
Masters Theses

Student Theses and Dissertations

1952

The effect of impeller speed and air-volume on the flotation rate with respect to particle size

William Edward Horst

Follow this and additional works at: https://scholarsmine.mst.edu/masters_theses

 Part of the [Metallurgy Commons](#)

Department:

Recommended Citation

Horst, William Edward, "The effect of impeller speed and air-volume on the flotation rate with respect to particle size" (1952). *Masters Theses*. 2050.

https://scholarsmine.mst.edu/masters_theses/2050

This thesis is brought to you by Scholars' Mine, a service of the Missouri S&T Library and Learning Resources. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

THE EFFECT OF IMPELLER SPEED AND AIR VOLUME ON THE
FLOTATION RATE WITH RESPECT TO PARTICLE SIZE

BY

WILLIAM EDWARD HORST

A

THESIS

SUBMITTED TO THE FACULTY OF THE
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
IN PARTIAL FULFILLMENT OF THE WORK REQUIRED FOR THE
DEGREE OF
MASTER OF SCIENCE IN METALLURGICAL ENGINEERING

ROLLA, MISSOURI

1952

APPROVED BY


ASSOCIATE PROFESSOR OF METALLURGICAL ENGINEERING

ACKNOWLEDGMENTS

THE AUTHOR WISHES TO THANK THE SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI FOR THE APPOINTMENT AS RESEARCH FELLOW IN METALLURGICAL ENGINEERING, THEREBY MAKING HIS GRADUATE WORK POSSIBLE.

THE AUTHOR SINCERELY THANKS DR. T. M. MORRIS OF THE METALLURGICAL ENGINEERING DEPARTMENT, SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI, FOR SUGGESTING THE PROBLEM AND HIS ENCOURAGEMENT AND ADVICE THROUGHOUT THE INVESTIGATION.

CONTENTS

	PAGE
ACKNOWLEDGMENTS.....	II
LIST OF ILLUSTRATIONS.....	IV
LIST OF TABLES.....	VII
INTRODUCTION.....	I
MEASUREMENT OF THE FLOTATION RATE...	5
PREPARATION OF CONCENTRATES FOR	
EXPERIMENTAL WORK.....	10
EXPERIMENTAL PROCEDURE.....	14
DISCUSSION OF RESULTS.....	68
SUMMARY OF CONCLUSIONS.....	79
APPENDIX.....	81
BIBLIOGRAPHY.....	101
VITA.....	103

LIST OF ILLUSTRATIONS

FIG.	PAGE
1. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-1.....	40
2. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-2.....	41
3. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-3.....	42
4. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-4.....	43
5. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-5.....	44
6. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-1.....	45
7. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-2.....	46
8. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-3.....	47
9. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-4.....	48
10. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-5.....	49
11. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-1.....	50

Fig.	PAGE
13. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-3.....	52
14. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-4.....	53
15. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-5.....	54
16. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-1.....	55
17. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-2.....	56
18. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-3.....	57
19. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-4.....	58
20. CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-5.....	59
21. VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, AIR VOLUME CONSTANT (1.0 LITER PER MIN.).....	62
22. VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, AIR VOLUME CONSTANT (2.0 LITERS PER MIN.).....	63

FIG.	PAGE
23. VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, AIR VOLUME CONSTANT (3.0 LITERS PER MIN.).....	64
24. VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, IMPELLER SPEED CONSTANT (863 RPM).....	65
25. VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, IMPELLER SPEED CONSTANT (1294 RPM).....	66
26 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, IMPELLER SPEED CONSTANT (2048 RPM).....	67

LIST OF TABLES

TABLE	PAGE
1. CALCULATED DATA FOR 89 MICRON SIZE FRACTION OF TEST 1-1.....	8
2. SIZE DISTRIBUTION OF 330 GRAM SAMPLE OF -35 MESH ORE.....	10
3. SIZE DISTRIBUTION OF 100 GRAM SAMPLE AFTER 2 MINUTES OF AGITATION IN CELL.....	11
4. SIZE DISTRIBUTION OF 100 GRAM SAMPLE AFTER 4 MINUTES OF AGITATION IN CELL.....	11
5. SIZE DISTRIBUTION OF 100 GRAM SAMPLE AFTER 8 MINUTES OF AGITATION IN CELL.....	11
6. DESIRED SIZE DISTRIBUTION OF CONCENTRATES FOR EXPERIMENTAL WORK.....	12
7. REAGENTS USED FOR CONCENTRATING TENNESSEE COPPER COMPANY ORE.	13
8. FLOTATION FEED FOR EACH RUN.....	15
9. OBSERVED DATA FROM FOUR RUNS HAVING THE SAME AIR VOLUME AND IMPELLER SPEED.....	17
10. MEAN DIAMETER OF PARTICLES IN EACH SIZE FRACTION.....	19

TABLE	PAGE
11. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 1-1.....	20
12. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 1-2.....	21
13. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 1-3.....	22
14. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 1-4.....	23
15. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 1-5.....	24
16. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 2-1.....	25
17. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 2-2.....	26
18. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 2-3.....	27
19. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 2-4.....	28
20. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 2-5.....	29
21. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 3-1.....	30
22. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 3-2.....	31

TABLE	PAGE
24. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 3-4.....	33
25. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 3-5.....	34
26. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 4-1.....	35
27. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 4-2.....	36
28. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 4-3.....	37
29. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 4-4.....	38
30. SIZE DISTRIBUTION OF PARTICLES IN FROTH, TEST 4-5.....	39
31. CALCULATED FLOTATION RATE CONSTANTS.....	60
32. CALCULATED FLOTATION RATE CONSTANTS.....	61
33. CALCULATED DATA FOR TEST 1-1.....	81
34. CALCULATED DATA FOR TEST 1-2.....	82
35. CALCULATED DATA FOR TEST 1-3.....	83
36. CALCULATED DATA FOR TEST 1-4.....	84
37. CALCULATED DATA FOR TEST 1-5.....	85
38. CALCULATED DATA FOR TEST 2-1.....	86

TABLE	PAGE
41. CALCULATED DATA FOR TEST 2-4.....	89
42. CALCULATED DATA FOR TEST 2-5.....	90
43. CALCULATED DATA FOR TEST 3-1.....	91
44. CALCULATED DATA FOR TEST 3-2.....	92
45. CALCULATED DATA FOR TEST 3-3.....	93
46. CALCULATED DATA FOR TEST 3-4.....	94
47. CALCULATED DATA FOR TEST 3-5.....	95
48. CALCULATED DATA FOR TEST 4-1.....	96
49. CALCULATED DATA FOR TEST 4-2.....	97
50. CALCULATED DATA FOR TEST 4-3.....	98
51. CALCULATED DATA FOR TEST 4-4.....	99
52. CALCULATED DATA FOR TEST 4-5.....	100

INTRODUCTION

IN THE EARLY DAYS OF MINING, THE ORE DEPOSITS WERE HIGH GRADE AND THE ORE COULD BE SENT DIRECTLY TO THE SMELTER. SINCE THIS TIME, THE HIGH GRADE DEPOSITS HAVE ALMOST VANISHED AND LOW GRADE ORES HAD TO BE MINED. THE NEED FOR CONCENTRATING THE MINED ORE BECAME APPARENT AND VARIOUS CONCENTRATING DEVICES SUCH AS JIGS AND TABLES WERE DEVELOPED.

TODAY THE ORE BEING MINED IS LOW GRADE AND THE MINERALIZATION HAS BECOME VERY COMPLEX. IN ORDER TO CONCENTRATE A COMPLEX ORE, THE REQUIREMENT OF GRINDING THE ORE VERY FINE IS IMPOSED. THE PROCESS OF FLOTATION WAS DEVELOPED TO CONCENTRATE THE FINELY GROUND ORE PARTICLES; HOWEVER, THE FINER SIZE FRACTIONS OF THE ORE STILL PRESENT A CONCENTRATING PROBLEM.

THE FACT HAS BEEN ESTABLISHED THAT THE FLOTATION RATE WHICH IS THE RECOVERY THAT CAN BE ATTAINED DURING A GIVEN TIME INTERVAL VARIES WITH PARTICLE SIZE.⁽¹⁾ THE FLOTATION

(1) MORRIS, T. M., MEASUREMENT OF FLOTATION RATE AS A FUNCTION OF PARTICLE SIZE, THESIS, MISSOURI SCHOOL OF MINES AND METALLURGY, ROLLA, MO., 1950.

RATE INCREASES WITH AN INCREASE IN PARTICLE SIZE UNTIL THE MAXIMUM FLOTATION RATE IS REACHED. MORRIS FOUND THE MAXIMUM FLOTATION RATE TO OCCUR IN THE SIZE RANGE OF 50 TO 60 MICRONS FOR COPPER AND PYRITE. AFTER THE MAXIMUM FLOTATION RATE IS REACHED, THE FLOTATION RATE DECREASES WITH AN INCREASE IN PARTICLE SIZE.

THE RESULTS OF THE INVESTIGATION IN WHICH THE IMPELLER SPEED AND AIR VOLUME ARE VARIED INDICATES WHAT EFFECTS THESE VARIABLES HAVE ON THE FLOTATION RATE IN REGARD TO THE PARTICLE SIZE. KNOWLEDGE OF THESE EFFECTS WOULD BE OF GREAT IMPORTANCE IN DETERMINING THE IMPELLER SPEED AND AIR VOLUME NECESSARY FOR EACH FLOTATION CELL IN A BANK OF FLOTATION CELLS IN ORDER TO ATTAIN THE MAXIMUM RECOVERY. IMPELLER SPEED AND VOLUME OF AIR ARE TWO IMPORTANT FACTORS UPON WHICH THE FLOTATION RATE OF VARIOUS SIZES OF PARTICLES DEPENDS.

THE PROBLEM OF MEASURING THE FLOTATION RATE HAS BEEN CONSIDERED BY MANY INVESTIGATORS AND THEIR METHODS OF EXPRESSING THE FLOTATION RATE HAVE BEEN VARIED. IN ORDER TO COMPARE FLOTATION RATES, IT IS MORE SATISFACTORY TO COMPARE STRAIGHT LINES THAN EXPONENTIAL CURVES WHICH RESULT FROM PLOTTING CUMULATIVE RECOVERY VERSUS CUMULATIVE FLOTATION TIME FROM THE RESULTS OF A FLOTATION TEST. THE EQUATION FROM THIS TYPE OF EXPONENTIAL CURVE WAS EXPRESSED IN 1935 BY H. GARCIA ZUNIGA⁽²⁾ TO BE,

(2) ZUNIGA, H. GARCIA, BOL. MINERO SOC. NACL. MINERIA, CHILE. VOL. 47, PP. 83-86, 1935.

$$R = R(1 - e^{-KT})$$

WHERE R = AMOUNT RECOVERY

R = ORIGINAL AMOUNT

T = FLOTATION TIME

K = A CONSTANT.

THE EQUATION MAY BE REARRANGED AND THE RESULTING FORM WILL BE

$$k = \frac{1}{t} \ln \frac{R}{R-R}$$

THIS FORM OF THE EQUATION IS COMPARABLE TO A UNIMOLECULAR FIRST ORDER REACTION, (3) AND WAS USED BY MORRIS (4) IN

(3) PRUTTON, C. F., AND MARON, S. H., FUNDAMENTAL PRINCIPLES OF PHYSICAL CHEMISTRY, PP. 608-650, NEW YORK, THE MACMILLAN COMPANY, 1948.

(4) MORRIS, T. M., OP. CIT.

MEASURING THE FLOTATION RATE CONSTANT, K, FOR VARIOUS PARTICLE SIZES USED IN FLOTATION TESTS THAT HE CONDUCTED.

VOLKOVA (5) SUGGESTED THAT AN EQUATION SIMILAR IN FORM

(5) VOLKOVA, Z., ACTA PHYSICOCHEMICA U.R.S.S., VOL. 22, P. 331, 1947.

TO A SECOND ORDER REACTION EQUATION SHOULD APPLY UNDER CERTAIN CONDITIONS TO THE EXPONENTIAL CURVE, BUT HE GAVE NO EXPERIMENTAL CONFIRMATION. ARBITER (6) GAVE A PRESENTATION

(6) ARBITER, NATHANIEL, FLOTATION RATES AND FLOTATION EFFICIENCY: AM. INST. MIN. MET. TRANS., T. P. 3193, P. 991, 1951.

OF THE USE OF A SECOND ORDER REACTION EQUATION AND SUPPORTED IT WITH EXPERIMENTAL FLOTATION RESULTS. THIS TYPE OF EQUATION IS EXPRESSED AS

$$R = \frac{A^2 k t}{1 + A k t}$$

WHERE R = CUMULATIVE RECOVERY

T = FLOTATION TIME

A = MAXIMUM POSSIBLE RECOVERY

K = A CONSTANT.

MEASUREMENT OF THE FLOTATION RATE

THE LAW OF MASS ACTION WHICH STATES THAT THE RATE OF A CHEMICAL REACTION IS PROPORTIONAL TO THE ACTIVE MASSES OF THE REACTING SUBSTANCES AT ANY TIME MAY BE USED AS A BASIS FOR DETERMINING THE EQUATION OF THE EXPONENTIAL CURVE RESULTING FROM A PLOT OF RECOVERY VERSUS TIME. THE APPLICATION OF THIS LAW TO FLOTATION WOULD INVOLVE THE MODIFICATIONS OF THE TERMS FLOTATION REACTION FOR CHEMICAL REACTION AND FLOTABLE MASSES FOR ACTIVE MASSES. A REACTION OF THIS NATURE MAY BE OF THE FOLLOWING TYPE;



HOWEVER, THE EXACT MECHANISM IS NOT KNOWN. DURING THIS OPERATION THE CONCENTRATION OF AIR IS KEPT CONSTANT. WITH THIS CONDITION EXISTING THE POSSIBILITY EXISTS THAT THE REACTION WOULD ACT SIMILAR TO A FIRST ORDER REACTION, AND MAY BE CLASSIFIED AS A PSEUDO-FIRST-ORDER REACTION⁽⁷⁾.

(7) HOUGEN, O. A. AND WATSON, K. M., CHEMICAL PROCESS PRINCIPLES, PART THREE, KINETICS AND CATALYSIS, P. 828, NEW YORK, JOHN WILEY AND SONS, 1947.

IN THIS CASE ONLY THE REACTANT A, THE SOLIDS, WOULD AFFECT THE RATE OF THE REACTION. SIMILARLY IF 1.5 OR 2 A (SOLIDS) WOULD REACT WITH AIR TO FORM THE PRODUCT (FROTH), THE REACTIONS WOULD BE CLASSIFIED AS A PSEUDO-THREE-HALVES-ORDER OR PSEUDO-SECOND-ORDER REACTION RESPECTIVELY.

THE MATERIAL USED IN THE INVESTIGATION WAS PYRITE-PYRRHOTITE CONCENTRATE. SINCE ALL OF THE MATERIAL HAD

BEEN FLOATED, IT WAS ASSUMED THAT ALL OF THE MATERIAL WAS CAPABLE OF BEING REFLOATED. THIS ASSUMPTION IS WITHIN REASON; HOWEVER, OXIDATION OF THE PARTICLES WOULD TEND TO DEPRESS THEM.

FIRST AND SECOND ORDER RATE EQUATIONS WERE TRIED IN ORDER TO EVALUATE THE FLOTATION RATE FROM THE EXPERIMENTAL RESULTS. THESE METHODS DID NOT FIT THE DATA AS WELL AS WHEN USING A THREE-HALVES ORDER RATE EQUATION. LAIDLER⁽⁸⁾

(8) LAIDLER, K. J., CHEMICAL KINETICS, P. 13, NEW YORK, MCGRAW-HILL BOOK COMPANY, 1950.

EXPLAINS THAT THE MOST DIRECT METHOD OF FINDING THE ORDER OF A REACTION IS TO TAKE THE VARIOUS INTEGRATED RATE EQUATIONS AND DETERMINE WHICH ONE BEST DESCRIBES THE REACTION. THIS PROCEDURE INVOLVES THE DETERMINATION OF THE SPECIFIC RATE CONSTANT WHICH SHOULD NOT DRIFT AS THE VALUES OF TIME INCREASE. THIS METHOD IS NOT VERY SENSITIVE FOR DISTINGUISHING BETWEEN ORDERS SUCH AS UNITY AND THREE-HALVES.

SINCE THE THREE-HALVES ORDER RATE EQUATION FITS THE EXPERIMENTAL RESULTS BEST OF THE THREE RATE EQUATIONS, IT WAS CHOSEN TO EVALUATE THE FLOTATION RATE. IT MUST BE REMEMBERED THAT EVALUATING THE FLOTATION RATE IS THE IMPORTANT FACTOR, AND NO ATTEMPT IS MADE TO ESTABLISH THE ORDER OF THE REACTION SINCE THE EXACT MECHANISM IS NOT KNOWN. THE RATE OF A THREE-HALVES ORDER REACTION MAY BE

EXPRESSED AS

$$\frac{DX}{DT} = K(A-X)^{1.5} \quad (\text{Eq. 1})$$

WHERE X = CUMULATIVE RECOVERY

A = INITIAL CONCENTRATION

T = FLOTATION TIME

K = A CONSTANT, FLOTATION RATE CONSTANT.

INTEGRATION OF EQUATION 1 GIVES THE EQUATION

$$\frac{1}{(A-X)^{\frac{1}{2}}} = \frac{K}{2} T + \frac{1}{A^{\frac{1}{2}}}. \quad (\text{Eq. 2})$$

BY PLOTTING $1/(A-X)^{\frac{1}{2}}$ VERSUS THE FLOTATION TIME, T , THE FLOTATION RATE CONSTANT, K , CAN BE DETERMINED SINCE IT WILL BE EQUAL TO TWICE THE SLOPE OF THE RESULTING LINE. THE ORDINATE INTERCEPT WOULD BE EQUAL TO $1/A^{\frac{1}{2}}$, AND IF A IS 100 PER CENT, THIS INTERCEPT SHOULD BE $0.1(\text{PER CENT})^{-\frac{1}{2}}$.

THE FLOTATION RATE CONSTANT AND THE INTERCEPT WERE CALCULATED BY THE METHOD OF LEAST SQUARES⁽⁹⁾ AFTER THE DATA

(9) HOUGEN, O. A., AND WATSON, K. M., OP. CIT., PP. 938-942.

WAS PLOTTED IN ACCORDANCE WITH EQUATION 2. FOR AN EQUATION OF A STRAIGHT LINE

$$Y = A + BX. \quad (\text{Eq. 3})$$

THE EQUATIONS WITH RESPECT TO THE CONSTANTS A AND B USING THE METHOD OF LEAST SQUARES ARE

$$NA + B \sum X - \sum Y = 0 \quad (\text{Eq. 4})$$

$$A \sum X + B \sum X^2 - \sum YX = 0 \quad (\text{Eq. 5})$$

WHERE N IS THE NUMBER OF OBSERVATIONS. SOLVING EQUATIONS

4 AND 5 SIMULTANEOUSLY FOR THE CONSTANTS A AND B GIVES

$$A = \frac{\sum Y \sum X^2 - \sum YX \sum X}{N \sum X^2 - (\sum X)^2} \quad (\text{EQ. 6})$$

AND

$$B = \frac{\sum Y \sum X - N \sum YX}{(\sum X)^2 - N \sum X^2} \quad (\text{EQ. 7})$$

THE CONSTANTS IN THE RATE EQUATION, EQUATION 2, WHICH IS ALSO THE EQUATION OF A STRAIGHT LINE MAY BE SUBSTITUTED FOR THEIR EQUALS INTO EQUATIONS 6 AND 7. THAT IS,

$$\frac{K}{2} = B$$

AND

$$\frac{1}{A^2} = A.$$

THEREFORE IT FOLLOWS THAT,

$$\frac{1}{A^2} = \frac{\sum Y \sum X^2 - \sum YX \sum X}{N \sum X^2 - (\sum X)^2}$$

AND

$$K = \frac{2(\sum Y \sum X - N \sum YX)}{(\sum X)^2 - N \sum X^2}.$$

AN EXAMPLE OF THE CALCULATIONS IS SHOWN USING THE DATA FOR THE 89 MICRON SIZE FRACTION OF TEST 1-1.

TABLE I

CALCULATED DATA FOR 89 MICRON SIZE FRACTION OF TEST 1-1

TIME (SEC.)	% REC.	A-X	$1/(A-X)^2$	τ^2	$\tau/(A-X)^2$
20	22.75	77.25	0.1138	400	2.276
40	12.47	64.78	0.1242	1600	4.968
60	8.14	56.64	0.1329	3600	7.974
90	12.10	44.54	0.1498	8100	13.482
<u>150</u>	15.90	28.64	<u>0.1868</u>	<u>22500</u>	<u>28.020</u>
360			0.7075	36200	56.720

$$\frac{1}{A^2} = \frac{(0.7075)(36200) - (56.720)(360)}{(5)(36200) - (360)^2}$$

$$\frac{1}{A^2} = 0.1012 \frac{1}{(\text{PER CENT})^2}$$

$$K = 2 \frac{(0.7075)(360) - 5(56.720)}{(360)^2 - 5(36200)}$$

$$K = 0.001125 \frac{1}{(\text{SEC.})(\text{PER CENT})^2}$$

$$K = (0.001125)(60)$$

$$K = 0.0675 \frac{1}{(\text{MIN.})(\text{PER CENT})^2}$$

PREPARATION OF CONCENTRATES FOR EXPERIMENTAL WORK

THREE ATTRITION TESTS WERE MADE ON TENNESSEE COPPER COMPANY ORE ⁽¹⁰⁾ THAT HAD BEEN CRUSHED TO $-\frac{1}{4}$ INCH IN A JAW

(10) TAGGART, A. F., HANDBOOK OF MINERAL DRESSING, CHAP. 2, PP. 67-68, NEW YORK, JOHN WILEY AND SONS, 1945.

CRUSHER AND GROUND TO -35 MESH IN ROLLS. A 330 GRAM SAMPLE OF THE -35 MESH ORE WAS THOROUGHLY MIXED AND ROLLED ON A ROLLING CLOTH. THEN THREE 100 GRAM SAMPLES WERE WEIGHED FOR SUBSEQUENT TREATMENT.

THE SIZE DISTRIBUTION OF THE 330 GRAM SAMPLE OF -35 MESH ORE IS SHOWN IN TABLE 2. TABLES 3, 4, AND 5 SHOW THE SIZE DISTRIBUTION OF THE THREE 100 GRAM SAMPLES AFTER THEY HAD BEEN AGITATED IN A MECHANICAL TYPE FLOTATION CELL, WITH

TABLE 2
SIZE DISTRIBUTION OF 330 GRAM SAMPLE
OF -35 MESH ORE

SIZE MESH	WT. HELD (GMS)	PER CENT HELD	CUM. PER CENT HELD
-35, +48	72.8	22.13	22.13
-48, +65	65.0	19.76	41.89
-65, +100	56.9	17.29	59.18
-100, +150	39.0	11.85	71.03
-150, +200	27.6	8.39	79.42
-200	<u>67.7</u>	<u>20.58</u>	100.00
SUM	329.0	100.00	

TABLE 3

SIZE DISTRIBUTION OF 100 GRAM SAMPLE
AFTER 2 MINUTES OF AGITATION IN CELL

SIZE MESH	WT. HELD (GMS)	PER CENT HELD	CUM. PER CENT HELD
-35, +48	22.1	22.48	22.48
-48, +65	18.8	19.13	41.61
-65, +100	17.0	17.29	58.90
-100, +150	11.5	11.70	70.60
-150, +200	8.2	8.34	78.94
-200	<u>20.7</u>	<u>21.06</u>	100.00
SUM	329.0	100.00	

TABLE 4

SIZE DISTRIBUTION OF 100 GRAM SAMPLE
AFTER 4 MINUTES OF AGITATION IN CELL

SIZE MESH	WT. HELD (GMS)	PER CENT HELD	CUM. PER CENT HELD
-35, +48	20.7	21.19	21.19
-48, +65	18.6	19.04	40.23
-65, +100	16.9	17.30	57.53
-100, +150	11.7	11.97	69.50
-150, +200	8.1	8.29	77.79
-200	<u>21.7</u>	<u>22.21</u>	100.00
SUM	97.7	100.00	

TABLE 5

SIZE DISTRIBUTION OF 100 GRAM SAMPLE
AFTER 8 MINUTES OF AGITATION IN CELL

SIZE MESH	WT. HELD (GMS)	PER CENT HELD	CUM. PER CENT HELD
-35, +48	20.7	21.27	21.27
-48, +65	19.0	19.53	40.80
-65, +100	16.9	17.37	58.17
-100, +150	11.5	11.82	69.99
-150, +200	7.9	8.12	78.11
-200	<u>21.3</u>	<u>21.89</u>	100.00
SUM	97.3	100.00	

700 CC. OF WATER. ALL OF THE SAMPLES WERE SCREENED FOR 15 MINUTES USING A RO-TAP TESTING SIEVE SHAKER. THE AGITATION TIME IN THE FLOTATION CELL FOR THE THREE SAMPLES WAS 2, 4, AND 8 MINUTES RESPECTIVELY.

THE RESULTS OF THE ATTRITION TESTS SHOWED THAT THE SIZE OF THE PARTICLES OF THE TENNESSEE COPPER COMPANY ORE REMAINED, WITHIN REASON, THE SAME AFTER BEING SUBJECTED TO AGITATION FOR VARIED PERIODS OF TIME. THEREFORE THIS ORE WAS FOUND SUITABLE TO USE IN PREPARING PYRITE CONCENTRATE FOR USE IN THE EXPERIMENTAL WORK. IT IS VERY IMPORTANT THAT THE SIZE OF THE PARTICLES IN THE CONCENTRATES REMAIN CONSTANT DURING THE EXPERIMENTAL WORK IN ORDER TO ATTAIN ACCURATE RESULTS SINCE THE FLOTATION RATE CONSTANT WAS STUDIED WITH RESPECT TO PARTICLE SIZE.

THE NEXT STEP REQUIRED WAS THE PREPARATION OF 10,000 GRAMS OF PYRITE CONCENTRATE FROM THE TENNESSEE COPPER COMPANY ORE. THIS CONCENTRATE ALSO CONTAINED SOME PYRRHOTITE. THE DESIRED SIZE DISTRIBUTION OF THE CONCENTRATE IS SHOWN IN TABLE 6.

TABLE 6
DESIRED SIZE DISTRIBUTION OF CONCENTRATES
FOR EXPERIMENTAL WORK

SIZE MESH	PER CENT	WEIGHT (GMS)
-48, +65	6	600
-65, +100	8	800
-100, +150	9	900
-150, +200	12	1200
-200	65	6500
SUM	100	10000

A 20,000 GRAM PORTION OF ORE, CHIEFLY $-3/4$ INCH SIZE, WAS CRUSHED IN A JAW CRUSHER TO $-3/8$ INCH AND GROUND IN ROLLS. THE PRODUCT FROM THE ROLLS WAS SCREENED ON A 48 MESH SCREEN AND THE OVERSIZE MATERIAL WAS GIVEN ANOTHER PASS THROUGH THE ROLLS. THIS PROCEDURE WAS REPEATED UNTIL ALL OF THE MATERIAL PASSED THE 48 MESH SCREEN.

THE -48 MESH ORE WAS CONCENTRATED IN A 500 GRAM FAGERGREN FLOTATION MACHINE. THE ROUGHER CONCENTRATE WAS CLEANED TWICE. THE FINAL CLEANED CONCENTRATE WAS FILTERED, WASHED WITH WATER, AND WASHED THREE TIMES WITH ACETONE. THE REAGENTS USED FOR CONCENTRATING THE ORE ARE SHOWN IN TABLE 7.

TABLE 7

REAGENTS USED FOR CONCENTRATING
TENNESSEE COPPER COMPANY ORE

REAGENT	LBS./TON
SODIUM XANTHATE	0.20
AMYL XANTHATE	0.10
SULFURIC ACID	(TO OBTAIN PH ABOUT 6)
PINE OIL	0.15

ABOUT 10,000 GRAMS OF PYRITE-PYRRHOTITE CONCENTRATE WAS PRODUCED. A RO-TAP TESTING SIEVE SHAKER WAS USED TO SIZE THE CONCENTRATE. LOTS OF 200 GRAMS EACH WERE SCREENED FOR 20 MINUTES. THE FINAL SIZE DISTRIBUTION OF THE CONCENTRATE WAS IN CLOSE AGREEMENT WITH THE DESIRED DISTRIBUTION AS SHOWN IN TABLE 6. EACH SIZE FRACTION OF THE CONCENTRATE WAS CAREFULLY ROLLED TO ASSURE UNIFORMITY. THE CONCENTRATE WAS THEN IN THE FINAL STAGE, AND THE EXPERIMENTAL WORK BEGAN.

EXPERIMENTAL PROCEDURE

THE PRELIMINARY TESTS AND FINAL TESTS WERE MADE USING A 250 GRAM MECHANICAL TYPE FLOTATION MACHINE SIMILAR TO THE ONE DESCRIBED BY W. F. DIETRICH⁽¹¹⁾ ET AL. THE CELL

(11) DIETRICH, W. F., ENGEL, A. L., AND GUGGENHEIM, MORRIS, U. S. BUR. MINES REPT. INV. 3328, P. 26, 1937.

WAS CHARGED WITH 75 GRAMS OF CONCENTRATE AND 700 CC. OF WATER. A SERIES OF PRELIMINARY TESTS WERE MADE TO DETERMINE THE OPTIMUM CONDITIONS FOR CONDUCTING THE FINAL TESTS. FROM THESE TESTS IT WAS FOUND THAT THE AVERAGE PH DURING FLOTATION REACHED A CRITICAL POINT AROUND 3.5. ON EITHER SIDE OF A PH OF 3.5 THE RECOVERY AND FLOTATION RATE WERE MARKEDLY DECREASED.

POTASSIUM ETHYL XANTHATE WAS THE COLLECTOR USED. AS THE AMOUNT OF XANTHATE WAS INCREASED THE RECOVERY ALSO INCREASED. THE RECOVERY REACHED A MAXIMUM WHEN THE XANTHATE ADDITION WAS 37 MILLIGRAMS PER 75 GRAMS OF CONCENTRATE FED TO THE CELL. THIS INDICATES THAT ALL OF THE PARTICLES IN THE CELL ARE ABLE TO GAIN MAXIMUM COLLECTOR COATING. THIS IS NECESSARY TO GIVE ALL OF THE PARTICLES THE MAXIMUM OPPORTUNITY TO BE FLOATABLE.

TERPINEOL WAS USED AS THE FROTHING AGENT IN THE AMOUNT OF 10 MILLIGRAMS PER 75 GRAMS OF CONCENTRATE FED TO THE CELL.

TWENTY FINAL TESTS WERE MADE VARYING THE VOLUME OF AIR AND IMPELLER SPEED. COMPRESSED AIR WAS FED TO THE CELL. A GAUGE, CALIBRATED IN LITERS PER MINUTE, WAS CONNECTED IN THE AIR LINE SO DIRECT READINGS COULD BE MADE. THE IMPELLER SPEEDS WERE 863, 1294, 1725 AND 2048 REVOLUTIONS PER MINUTE. FIVE AIR VOLUMES, 1.0, 2.0, 2.5, 3.0, AND 3.5 LITERS PER MINUTE, WERE USED FOR EACH IMPELLER SPEED.

TABLE 8 SHOWS THE CONSTITUENTS CHARGED TO THE FLOTATION CELL FOR EACH RUN. FOUR RUNS WERE MADE HAVING THE SAME AIR VOLUME AND IMPELLER SPEED, AND THE THREE RUNS HAVING THE MOST SIMILAR FLOTATION RATE CONSTANTS WERE COMBINED TO MAKE ONE TEST. THIS WAS NECESSARY IN ORDER TO HAVE A SUFFICIENT AMOUNT OF SOLIDS, ABOUT 20 GRAMS, IN EACH FROTH BEFORE BEING SIZED. IF THE WEIGHT OF THE MATERIAL CHARGED TO THE INFRASIZER IS TOO SMALL, THE THREE FINER SIZE FRACTIONS HAVE THE TENDENCY TO HOLD UP AND NOT ELUTRIATE IN THE PROPER MANNER. IT IS ALSO IMPORTANT TO HAVE SUFFICIENT WEIGHTS OF MATERIAL IN EACH SIZE FRACTION SO THAT A SMALL LOSS OF MATERIAL WOULD NOT NOTICEABLY AFFECT THE RESULTS.

TABLE 8
FLOTATION FEED FOR EACH RUN

CONSTITUENT	AMOUNT
PYRITE-PYRRHOTITE CONCENTRATE	75 GMS.
DISTILLED WATER	700 CC.
SULFURIC ACID (CONC.)	0.2 CC.
POTASSIUM ETHYL XANTHATE	37 MG.
TERPINEOL	10 MG.

THE POTASSIUM ETHYL XANTHATE THAT WAS USED HAD BEEN
PURIFIED.⁽¹²⁾ THIS WAS DONE EACH DAY A TEST WAS MADE,

(12) WARK, I. W., AND COX, A. B., PRINCIPLES OF
FLOTATION, I - AN EXPERIMENTAL STUDY OF THE
EFFECT OF XANTHATES ON CONTACT ANGLES AT
MINERAL SURFACES: AM. INST. MIN. MET. TRANS.,
VOL. 26, PP. 193-194, 1935.

AND ENOUGH PURIFIED XANTHATE WAS MADE FOR USE IN FOUR RUNS.

THE FLOTATION CELL WAS CHARGED IN THE FOLLOWING MANNER.
THE SULFURIC ACID WAS ADDED TO 700 CC. OF DISTILLED WATER
AND APPROXIMATELY 400 CC. OF THE RESULTING MIXTURE WAS
POURED INTO THE CELL. ONE DROP, 10 MG., OF TERPINEOL WAS
ADDED TO THE REMAINING WATER ACID MIXTURE. THEN 75 GRAMS
OF PYRITE-PYRRHOTITE CONCENTRATE HAVING THE SIZE DISTRIBUTION
AS SHOWN IN TABLE 6 WAS ADDED TO THE CELL. NEXT,
37 MG. OF PURIFIED POTASSIUM ETHYL XANTHATE WAS ADDED TO
THE CELL FOLLOWED BY THE REMAINING PORTION OF THE WATER
ACID MIXTURE CONTAINING THE TERPINEOL. THE AIR, MOTOR,
AND A STOP WATCH WERE STARTED SIMULTANEOUSLY AND FLOTATION
BEGAN. DURING THE FLOTATION OPERATION DISTILLED WATER,
CONTAINING 10 MG. OF TERPINEOL PER 700 CC., WAS ADDED TO
KEEP THE PULP LEVEL IN THE CELL CONSTANT.

THE FROTH FOR THE FIRST 20 SECONDS WAS COLLECTED IN
A PAN. THE FROTH FROM THE SECOND 20 SECOND INTERVAL WAS
COLLECTED IN A SECOND PAN. THIS PROCEDURE WAS REPEATED
FOR THREE MORE TIME INTERVALS OF 20, 30, AND 60 SECONDS.
FROTH WAS ALSO COLLECTED IN A SIXTH PAN TO ASSURE THAT
FLOTATION HAD NOT STOPPED PRIOR TO THE TERMINATION OF THE

FIFTH TIME INTERVAL. THE FROTH APPEARED TO BE BARREN DURING THE FIRST 60 SECOND OF THE SIXTH TIME INTERVAL. AFTER EACH RUN THE FROTH COLLECTED IN THE SIXTH PAN WAS COMBINED WITH THE FINAL TAILINGS.

IT WAS IMPORTANT TO KEEP THE CONCENTRATION OF FROTHING AGENT, TERPINEOL, CONSTANT THROUGHOUT EACH RUN SINCE THIS REAGENT AFFECTS THE SURFACE TENSION. CONSEQUENTLY, IT ALSO AFFECTS THE SIZE DISTRIBUTION OF THE BUBBLES.

EACH FROTH WAS FILTERED, WASHED TWICE WITH ACETONE, DRIED, AND WEIGHED. A PLOT OF TIME VERSUS $1/(A-X)^{\frac{1}{2}}$ WAS MADE FOR EACH RUN TO DETERMINE THE FLOTATION RATE CONSTANT, K, FOR EACH RUN. AN EXAMPLE OF THE DATA THAT WAS

TABLE 9
OBSERVED DATA FROM FOUR RUNS HAVING THE
SAME AIR VOLUME AND IMPELLER SPEED

TEST 2-3		IMPELLER SPEED---2048 RPM AIR VOLUME---2.5 LITERS/MIN.			
RUN		1	2	3	4
GMS. OF SOLIDS IN FROTH AFTER					
20 SEC.		18.3	20.8	19.7	20.2
40 SEC.		10.4	10.8	15.0	11.6
60 SEC.		7.5	9.4	8.2	10.3
90 SEC.		7.3	8.8	7.2	8.0
150 SEC.		10.0	8.2	6.4	7.1
TAILS		<u>19.8</u>	<u>15.5</u>	<u>16.7</u>	<u>16.2</u>
SUM		73.3	73.5	73.2	73.4
K (1/(MIN.))(PER CENT) ^{$\frac{1}{2}$}		0.066	0.089	0.086	0.085

COLLECTED FOR THE FOUR RUNS IS SHOWN IN TABLE 9. ON THE BASIS OF THE FLOTATION RATE CONSTANT, K , RUNS 2, 3, AND 4 WERE COMBINED TO MAKE TEST 2-3. THAT IS, THE FROTHS FROM THE FIRST TIME INTERVAL WERE COMBINED, THE FROTHS FROM THE SECOND TIME INTERVAL WERE COMBINED, AND SO FORTH. LIKEWISE THE TAILINGS WERE COMBINED.

THE COMBINED FROTHS AND TAILINGS WERE EACH SCREENED FOR 40 MINUTES USING A RO-TAP TESTING SIEVE SHAKER. THE SCREENS USED WERE 35, 48, 65, 100, 150, AND 200 MESH. THE -200 MESH FRACTION WAS THEN ELUTRIATED WITH AIR FOR 2 HOURS USING A HAULTAIN INFRASIZER. THE RESULTING SIZE FRACTIONS FROM THE SCREENS AND INFRASIZER WERE WEIGHED TO THE NEAREST MILLIGRAM. THE MEAN DIAMETER OF THE PARTICLES IN EACH SIZE FRACTION IS SHOWN IN TABLE 10.⁽¹³⁾ THE LOSS DURING

(13) TAGGART, A. F., HANDBOOK OF MINERAL DRESSING, CHAP. 19, PP. 115-116, NEW YORK, JOHN WILEY AND SONS, 1945.

THE SIZING OPERATION VARIED FROM 2 TO 3 PER CENT. THIS LOSS WAS ASSUMED TO BE EQUALLY DISTRIBUTED THROUGHOUT THE SIZE FRACTIONS. THE VALIDITY OF THIS ASSUMPTION IS QUESTIONABLE; HOWEVER, THE SMALL PER CENTAGE OF MATERIAL THAT WAS LOST IN SIZING WOULD NOT SIGNIFICANTLY ALTER THE FINAL RESULTS.

THE DATA OBTAINED FROM THE TWENTY EXPERIMENTAL TESTS APPEARS IN THE TABLES 11 TO 30. THE CALCULATED DATA ARE INCLUDED IN THE APPENDIX. FIGURES 1 TO 20 WHICH FOLLOW

TABLE 10
MEAN DIAMETER OF PARTICLES IN EACH SIZE FRACTION

SIZE FRACTION		SIZE RANGE (MICRONS)	MEAN DIAMETER (MICRONS)
SCREEN (MESH)	-48, +65	208-295	252
	-65, +100	147-208	178
	-100, +150	104-147	126
	-150, +200	74-104	89
INFRASIZER (CONES)	1	46-74	60
	2	32-46	39
	3	23-32	27.5
	4	16-23	19.5
	5	11.5-16	13.8
	6	8-11.5	9.8
	7	LESS THAN 8	-8

THE EXPERIMENTAL RESULTS SHOW A GRAPHIC REPRESENTATION OF THE FINAL RESULTS. THE SLOPE OF THE LINES ON THESE FIGURES IS A MEASURE OF THE FLOTATION RATE. THE FLOTATION RATE CONSTANTS FOR ALL OF THE SIZE FRACTIONS FOR EACH TEST APPEAR IN TABLES 31 AND 32.

TABLE II

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST I-1

IMPELLER SPEED --- 1725 RPM

AIR VOLUME --- 1.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.058	0.039	0.027	0.058	0.203	10.428	10.813
178	0.769	0.522	0.352	0.834	2.115	14.568	19.160
126	2.642	1.656	1.207	2.349	3.552	7.260	18.666
89	5.279	2.892	1.889	2.807	3.690	6.646	23.203
60	20.102	12.896	8.034	9.101	9.172	17.865	77.170
39	5.110	3.090	2.135	2.499	2.254	5.681	20.769
27.5	3.418	2.250	1.298	2.280	2.123	4.389	15.758
19.5	2.337	1.348	1.482	1.846	1.705	3.061	11.779
13.8	1.812	0.791	0.774	0.861	0.902	2.350	7.490
9.8	0.924	0.417	0.254	0.224	0.252	1.428	3.499
-8	0.127	0.150	0.137	0.177	0.157	0.835	1.583
SUM	42.578	26.051	17.589	23.036	26.125	74.511	209.890
ORIGINAL GMS. OF FROTH	43.523	27.761	18.940	23.461	28.385	77.985	220.055

TABLE 12

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 1-2

IMPELLER SPEED --- 1725 RPM

AIR VOLUME --- 2.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.090	0.083	0.055	0.122	0.510	10.068	10.928
178	1.984	0.646	0.373	0.803	1.847	14.223	19.876
126	5.760	1.925	1.091	1.733	2.334	7.170	20.013
89	5.528	2.871	1.740	2.086	2.520	9.260	24.005
60	9.865	5.229	2.553	2.206	3.046	14.138	37.037
39	11.002	5.500	2.742	3.190	3.452	7.587	33.473
27.5	7.044	4.332	2.530	2.607	2.838	5.361	24.712
19.5	3.868	2.852	1.776	1.906	2.095	4.041	16.538
13.8	2.401	1.832	1.219	1.340	1.560	2.891	11.243
9.8	0.531	0.983	0.213	0.347	0.866	2.541	5.481
-8	2.745	1.963	1.626	1.958	1.421	3.774	13.487
SUM	50.818	28.216	15.918	18.298	22.489	81.054	216.793
ORIGINAL GMS. OF FROTH	52.508	29.196	16.807	19.191	23.868	82.196	223.766

TABLE 13

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 1-3

IMPELLER SPEED --- 1725 RPM

AIR VOLUME --- 2.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.060	0.050	0.079	0.120	0.178	10.817	11.304
178	1.057	0.940	0.956	1.097	1.250	14.695	19.995
126	3.670	2.756	2.326	2.016	1.939	7.515	20.222
89	6.519	3.745	2.630	2.283	2.174	6.414	23.765
60	12.331	5.031	3.554	2.459	1.475	11.363	36.213
39	12.017	8.300	3.459	2.367	2.808	4.062	33.013
27.5	7.580	4.773	2.920	2.432	2.241	5.176	25.122
19.5	4.220	3.274	2.036	1.757	1.668	3.860	16.815
13.8	2.656	2.152	1.425	1.310	1.330	2.309	11.182
9.8	1.142	1.033	0.738	0.522	0.696	1.474	5.605
-8	3.074	3.112	1.857	1.607	1.344	2.234	13.228
SUM	54.326	35.166	21.980	17.970	17.103	69.919	216.464
ORIGINAL GMS. OF FROTH	55.587	35.569	22.505	18.769	18.188	71.414	222.032

TABLE 14

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 1-4

IMPELLER SPEED --- 1725 RPM

AIR VOLUME --- 3.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.101	0.057	0.045	0.070	0.252	13.300	13.825
178	1.427	0.725	0.559	0.857	1.935	14.160	19.663
126	4.019	2.032	1.525	1.969	2.967	7.522	20.034
89	6.220	2.962	2.236	2.372	2.976	5.865	22.631
60	23.050	10.838	8.131	7.461	8.000	13.306	70.786
39	7.153	4.252	2.770	2.910	2.337	5.060	24.482
27.5	4.072	2.692	1.918	1.906	1.763	3.669	16.020
19.5	3.109	2.265	1.206	1.952	1.809	2.651	12.992
13.8	1.731	1.326	0.975	0.970	0.902	1.904	7.808
9.8	0.506	0.564	0.218	0.230	0.333	0.541	2.392
-8	0.449	0.328	0.186	0.233	0.248	0.408	1.852
SUM	51.837	28.041	19.769	20.930	23.522	68.386	212.485
ORIGINAL GMS. OF FROTH	53.506	28.640	21.000	21.257	24.326	70.111	218.840

TABLE 15

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 1-5

IMPELLER SPEED --- 1725 RPM

AIR VOLUME --- 3.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.081	0.070	0.051	0.087	0.240	13.187	13.716
178	1.187	1.022	0.686	1.000	1.827	14.433	20.155
126	4.337	2.780	1.757	2.112	2.500	6.503	19.989
89	7.246	3.574	2.148	2.251	2.427	4.255	21.901
60	16.045	4.753	2.485	2.162	6.003	12.040	43.488
39	10.857	7.453	3.599	3.302	2.629	4.537	32.377
27.5	8.412	4.719	2.682	2.459	1.588	3.440	23.300
19.5	4.826	3.165	1.912	1.886	1.153	3.190	16.132
13.8	3.017	2.175	1.386	1.450	0.217	1.987	10.232
9.8	0.967	0.430	0.643	0.633	0.127	0.428	3.228
-8	4.042	-----	4.632	1.141	0.385	0.447	10.647
SUM	61.017	30.141	21.981	18.483	19.096	64.447	215.165
ORIGINAL GMS. OF FROTH	62.350	34.119	19.410	19.525	20.485	65.137	221.026

TABLE 16

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-1

IMPELLER SPEED --- 2048 RPM

AIR VOLUME --- 1.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.095	0.134	0.230	0.618	1.588	8.402	11.067
178	0.545	0.895	1.178	2.241	3.316	11.221	19.396
126	1.978	2.560	2.334	2.660	2.460	6.611	18.603
89	4.002	3.651	2.652	2.740	2.529	7.415	22.989
60	18.820	11.967	6.835	6.898	6.874	27.750	79.144
39	4.691	3.179	2.027	2.105	2.268	7.440	21.710
27.5	3.210	2.130	1.392	1.340	1.523	6.625	16.220
19.5	2.120	1.849	1.037	0.848	1.466	5.036	12.356
13.8	1.269	0.972	0.227	0.739	0.749	3.542	7.498
9.8	0.707	0.622	0.264	0.212	0.233	0.926	2.964
-8	0.445	0.430	0.130	0.183	0.150	1.064	2.402
SUM	37.882	28.389	18.306	20.584	23.156	86.033	214.349
ORIGINAL GMS. OF FROTH	39.149	28.568	19.258	21.289	23.682	88.719	220.665

TABLE 17

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-2

IMPELLER SPEED --- 2048 RPM

AIR VOLUME --- 2.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.105	0.216	0.376	1.090	2.423	6.656	10.866
178	0.778	1.626	1.940	3.135	3.632	7.984	19.095
126	2.857	4.071	2.827	2.775	2.461	4.389	19.380
89	5.484	5.386	3.007	2.880	2.690	4.518	23.965
60	22.612	14.854	7.346	7.464	7.846	15.377	75.499
39	6.700	4.505	1.980	2.073	2.321	5.786	23.365
27.5	4.323	2.935	1.420	1.556	1.738	4.666	16.638
19.5	2.976	1.982	1.071	1.245	1.540	3.277	12.091
13.8	2.615	1.811	0.618	0.653	0.902	2.516	9.115
9.8	1.473	1.175	0.225	0.149	0.302	1.450	4.774
-8	<u>0.325</u>	<u>0.423</u>	<u>0.148</u>	<u>0.211</u>	<u>0.268</u>	<u>1.220</u>	<u>2.595</u>
SUM	50.248	38.984	20.958	23.231	26.123	57.839	217.383
ORIGINAL GMS. OF FROTH	50.579	39.230	21.672	24.045	26.824	59.590	221.940

TABLE 18

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-3

IMPELLER SPEED --- 2048 RPM

AIR VOLUME --- 2.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.074	0.209	0.452	1.157	2.251	6.862	11.005
178	0.738	1.657	2.507	3.160	3.290	8.095	19.447
126	3.278	4.090	3.586	2.629	1.935	3.992	19.510
89	6.731	5.079	3.751	2.621	2.021	3.680	23.883
60	25.896	13.282	9.285	6.860	6.031	13.271	74.625
39	8.337	4.890	2.646	2.300	1.595	4.188	23.956
27.5	5.273	3.619	1.808	1.622	1.308	3.736	17.366
19.5	3.685	2.245	1.651	1.615	1.073	2.679	12.948
13.8	2.663	0.902	1.252	0.871	0.863	1.504	8.055
9.8	0.977	0.589	0.461	0.546	0.590	0.615	3.778
-8	0.442	0.143	0.292	0.276	0.262	0.586	2.001
SUM	58.094	36.705	27.691	23.657	21.219	49.208	216.574
ORIGINAL GMS. OF FROTH	60.100	37.658	28.036	23.931	21.348	51.557	222.630

TABLE 19

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-4

IMPELLER SPEED --- 2048 RPM

AIR VOLUME --- 3.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.074	0.154	0.274	0.689	1.629	7.127	9.947
178	0.590	1.293	1.610	2.515	3.431	9.713	19.152
126	2.570	4.105	2.904	2.666	2.488	5.259	19.992
89	5.441	5.587	3.019	2.561	2.488	4.784	23.880
60	25.854	16.846	7.162	6.765	6.696	13.537	76.860
39	6.013	4.628	2.293	1.714	2.057	5.748	22.453
27.5	4.538	3.270	1.500	1.507	1.634	4.290	16.739
19.5	3.209	2.280	1.144	1.022	1.541	3.101	12.297
13.8	1.546	1.953	0.835	0.525	0.826	2.713	8.398
9.8	0.900	1.252	0.506	0.240	0.430	1.383	4.711
-8	<u>0.238</u>	<u>0.683</u>	<u>0.492</u>	<u>0.278</u>	<u>0.316</u>	<u>1.069</u>	<u>3.076</u>
SUM	50.973	42.051	21.739	20.482	23.536	58.724	217.505
ORIGINAL GMS. OF FROTH	52.190	42.387	22.056	21.300	24.236	60.501	222.670

TABLE 20

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-5

IMPELLER SPEED --- 2048 RPM

AIR VOLUME --- 3.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.121	0.202	0.325	0.763	1.903	6.921	10.235
178	0.968	1.653	1.878	2.424	3.171	8.058	18.152
126	3.892	4.158	2.690	2.042	1.914	3.931	18.627
89	7.720	5.033	2.661	2.019	1.992	3.485	22.910
60	32.297	14.399	6.684	5.253	6.380	12.114	77.127
39	8.415	4.462	2.418	2.035	1.901	3.787	23.018
27.5	5.394	3.126	1.659	1.376	1.509	2.825	15.889
19.5	3.526	2.279	1.492	1.154	1.418	2.019	11.888
13.8	2.569	1.224	1.157	0.545	0.840	1.013	7.348
9.8	1.706	0.552	0.808	0.243	0.408	0.771	4.488
-8	1.170	0.458	0.510	0.200	0.276	0.670	3.284
SUM	67.778	37.546	22.282	18.054	21.712	45.594	212.966
ORIGINAL GMS. OF FROTH	68.115	38.987	22.960	19.043	22.314	47.144	218.563

TABLE 21

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-1

IMPELLER SPEED --- 1294 RPM

AIR VOLUME --- 1.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.088	0.120	0.172	0.367	1.101	8.613	10.461
178	0.756	1.065	1.311	2.054	3.395	10.736	10.317
126	2.601	3.207	2.716	2.722	2.657	5.544	19.447
89	4.631	4.457	3.064	2.731	2.697	5.704	23.284
60	19.440	12.903	6.957	6.972	8.709	19.974	74.955
39	4.319	4.220	2.990	2.532	2.786	6.307	23.154
27.5	2.956	2.643	1.745	1.686	2.052	4.924	16.006
19.5	2.417	2.048	1.737	1.510	1.971	3.358	13.041
13.8	1.453	1.169	0.983	0.889	0.929	2.743	8.166
9.8	0.980	0.593	0.533	0.461	0.600	1.367	4.534
-8	0.334	0.273	0.301	0.261	0.441	1.766	3.376
SUM	39.975	32.698	22.509	22.185	27.338	71.036	215.741
ORIGINAL GMS. OF FROTH	40.554	34.119	22.537	22.694	28.142	72.462	220.508

TABLE 22

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-2

IMPELLER SPEED --- 1294 RPM

AIR VOLUME --- 2.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.118	0.129	0.142	0.248	0.690	9.290	10.617
178	1.000	1.306	1.156	1.606	2.800	12.155	20.023
126	3.176	3.445	2.282	2.200	2.398	5.991	19.492
89	5.471	4.593	2.468	2.198	2.373	6.149	23.252
60	20.246	14.460	6.901	5.954	6.690	20.840	75.091
39	6.092	3.718	2.220	2.310	3.082	6.813	24.235
27.5	3.415	2.568	1.539	1.548	1.981	5.022	16.073
19.5	2.500	2.149	1.540	1.394	1.743	3.410	12.736
13.8	1.437	1.123	1.084	0.896	1.188	2.168	7.896
9.8	0.685	0.782	0.465	0.239	0.625	1.028	3.824
-8	0.480	0.368	0.233	0.210	0.272	1.041	2.604
SUM	44.620	34.641	20.030	18.803	23.842	73.907	215.843
ORIGINAL GMS. OF FROTH	46.382	35.405	19.997	19.482	24.537	75.588	221.391

TABLE 23

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-3

IMPELLER SPEED --- 1294 RPM

AIR VOLUME --- 2.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.122	0.098	0.102	0.174	0.457	10.522	11.475
178	1.188	0.850	0.857	1.180	2.309	13.337	19.721
126	3.854	2.619	2.131	2.109	2.586	6.455	19.754
89	6.775	3.855	2.547	2.176	2.423	6.224	24.000
60	21.740	12.112	7.371	5.955	6.730	18.601	72.509
39	7.653	4.009	2.590	2.498	2.854	6.384	25.988
27.5	4.230	2.671	2.085	1.663	2.041	4.357	17.047
19.5	2.907	2.131	1.623	1.335	1.986	2.945	12.927
13.8	2.472	0.675	1.170	0.466	1.252	2.404	8.439
9.8	1.492	0.392	0.228	0.197	0.730	1.398	4.437
-8	0.618	0.437	0.232	0.205	0.412	0.956	2.860
SUM	53.051	29.849	20.936	17.958	23.780	73.583	219.157
ORIGINAL GMS. OF FROTH	53.825	31.376	20.610	18.893	23.952	75.058	223.714

TABLE 24

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-4

IMPELLER SPEED --- 1294 RPM

AIR VOLUME --- 3.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.110	0.097	0.101	0.199	0.528	10.587	11.622
178	1.106	0.904	0.927	1.431	2.576	13.545	20.489
126	3.651	2.821	2.316	2.441	2.588	6.392	20.179
89	6.700	4.117	2.720	2.454	2.505	6.092	24.588
60	22.550	12.150	6.660	6.066	6.907	19.186	73.519
39	7.904	4.209	2.928	2.418	2.366	4.933	24.758
27.5	4.649	2.806	1.875	1.865	1.920	3.634	16.749
19.5	3.020	2.273	1.399	1.565	1.870	2.918	13.045
13.8	2.640	1.317	1.151	0.492	0.968	1.420	7.988
9.8	1.169	0.630	0.727	0.314	0.469	0.749	4.058
-8	0.927	0.430	0.647	0.205	0.250	0.808	3.267
SUM	54.426	31.754	21.451	19.420	22.947	70.264	220.262
ORIGINAL GMS. OF FROTH	55.478	32.979	21.592	20.395	23.504	71.765	225.713

TABLE 25

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-5

IMPELLER SPEED --- 1294 RPM

AIR VOLUME --- 3.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.130	0.125	0.110	0.180	0.414	10.437	11.396
178	1.315	1.192	1.000	1.318	2.272	13.262	20.359
126	4.338	3.298	2.181	2.083	2.268	6.044	20.212
89	7.837	4.520	2.455	2.050	2.150	5.568	24.580
60	25.610	5.060	2.284	2.224	2.202	8.141	45.521
39	8.824	7.748	3.256	2.467	2.685	6.522	31.502
27.5	5.146	4.679	2.509	2.164	2.366	5.126	21.990
19.5	3.657	3.309	1.835	1.650	1.805	3.373	15.629
13.8	2.768	2.224	1.238	1.162	1.311	2.113	10.816
9.8	0.655	1.569	0.582	0.740	0.353	0.758	4.657
-8	0.390	4.531	2.239	1.488	2.106	2.333	13.087
SUM	60.679	38.255	19.689	17.526	19.932	63.677	219.749
ORIGINAL GMS. OF FROTH	62.975	37.183	20.024	18.226	20.640	64.862	223.910

TABLE 26

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-1

IMPELLER SPEED --- 863 RPM

AIR VOLUME --- 1.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS LN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.067	0.085	0.080	0.118	0.320	10.588	11.258
178	0.500	0.702	0.591	0.818	1.681	15.485	19.777
126	1.665	2.288	1.793	2.012	2.822	9.661	20.241
89	2.865	3.482	2.290	2.381	2.970	9.978	23.966
60	4.248	4.728	3.034	2.565	3.339	17.112	35.026
39	5.090	5.945	3.292	3.387	3.905	12.351	33.970
27.5	3.239	3.842	2.512	2.614	3.186	9.895	25.288
19.5	2.117	2.406	1.686	1.805	2.282	6.616	16.912
13.8	1.429	1.635	1.132	1.185	1.592	4.544	11.517
9.8	0.660	0.350	0.380	0.483	0.931	2.237	5.041
-8	<u>1.400</u>	<u>2.392</u>	<u>1.583</u>	<u>1.656</u>	<u>1.692</u>	<u>3.718</u>	<u>12.441</u>
SUM	23.280	27.855	18.373	19.024	24.720	102.185	215.437
ORIGINAL GMS. OF FROTH	24.342	28.691	18.997	19.755	25.614	104.984	222.383

TABLE 27

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-2

IMPELLER SPEED --- 863 RPM

AIR VOLUME --- 2.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.082	0.074	0.070	0.132	0.303	10.003	10.664
178	0.573	0.591	0.495	0.887	1.613	15.868	20.027
126	1.957	1.995	1.530	2.215	2.702	9.641	20.040
89	3.348	3.040	2.049	2.784	2.965	10.460	24.646
60	5.500	4.258	2.567	2.938	3.332	15.477	34.072
39	5.582	4.609	2.679	3.678	3.577	12.101	32.226
27.5	3.802	3.322	2.231	2.870	3.204	10.130	25.559
19.5	2.433	2.180	1.482	1.974	2.283	6.591	16.943
13.8	1.603	1.456	1.012	1.345	1.605	4.355	11.376
9.8	0.529	0.900	0.681	0.592	1.110	2.460	6.272
-8	<u>3.002</u>	<u>1.538</u>	<u>1.139</u>	<u>1.818</u>	<u>1.967</u>	<u>5.435</u>	<u>14.899</u>
SUM	28.411	23.963	15.935	21.233	24.661	102.521	216.724
ORIGINAL GMS. OF FROTH	28.471	24.974	16.550	21.950	25.307	104.335	221.587

TABLE 28

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-3

IMPELLER SPEED --- 863 RPM

AIR VOLUME --- 2.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.078	0.088	0.078	0.115	0.320	9.793	10.472
178	0.432	0.655	0.557	0.750	1.790	15.951	20.135
126	1.454	2.233	1.665	1.832	3.108	9.915	20.207
89	2.782	3.653	2.292	2.173	3.270	10.018	24.188
60	4.612	5.515	2.763	2.442	3.365	14.202	32.899
39	4.605	5.787	3.586	2.916	4.745	12.777	34.416
27.5	3.467	3.900	2.600	2.336	3.532	9.930	25.765
19.5	2.192	2.524	1.738	1.616	2.535	6.491	17.096
13.8	1.480	1.637	1.187	1.130	1.747	4.238	11.419
9.8	1.030	1.037	0.806	0.578	1.187	2.025	6.663
-8	<u>1.571</u>	<u>1.887</u>	<u>1.377</u>	<u>1.477</u>	<u>2.030</u>	<u>5.855</u>	<u>14.197</u>
SUM	23.703	28.916	18.649	17.365	27.629	101.195	217.457
ORIGINAL GMS. OF FROTH	24.332	29.847	19.139	17.871	28.428	102.863	222.480

TABLE 29

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-4

IMPELLER SPEED --- 863 RPM

AIR VOLUME --- 3.0 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.055	0.069	0.075	0.120	0.320	9.773	10.412
178	0.430	0.521	0.521	0.724	1.742	15.942	19.880
126	1.678	1.972	1.677	1.897	3.131	10.276	20.631
89	3.322	3.218	2.199	2.263	3.236	9.888	24.126
60	5.286	5.250	2.621	2.968	4.437	15.017	35.579
39	6.350	4.898	3.236	2.638	3.339	11.614	32.075
27.5	4.018	3.645	2.485	2.361	3.369	9.820	25.698
19.5	2.541	2.356	1.626	1.630	2.359	6.479	16.991
13.8	1.644	1.573	1.125	1.104	1.644	4.274	11.364
9.8	1.267	1.072	0.705	0.680	0.805	2.294	6.823
-8	<u>1.637</u>	<u>1.758</u>	<u>1.369</u>	<u>1.230</u>	<u>2.161</u>	<u>5.802</u>	<u>13.957</u>
SUM	28.228	26.332	17.639	17.615	26.543	101.179	217.536
ORIGINAL GMS. OF FROTH	29.075	27.026	18.335	18.226	27.364	102.655	222.681

TABLE 30

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-5

IMPELLER SPEED --- 863 RPM

AIR VOLUME --- 3.5 LITERS/MIN.

MEAN DIA. MICRONS	GRAMS OF SOLIDS IN FROTH AFTER					GMS. SOLIDS IN TAILS	TOTALS
	20 SEC.	40 SEC.	60 SEC.	90 SEC.	150 SEC.		
252	0.075	0.089	0.113	0.208	0.786	9.732	11.003
178	0.328	0.792	1.002	1.471	2.776	13.971	20.340
126	1.156	3.001	3.021	2.972	2.755	7.819	20.724
89	3.062	4.925	3.898	3.150	2.519	7.498	25.052
60	13.971	6.228	3.489	2.709	2.393	10.965	39.755
39	12.523	4.992	3.041	2.429	2.370	7.166	32.521
27.5	8.409	4.466	2.590	2.274	2.411	6.010	26.160
19.5	4.750	3.015	1.835	1.620	1.818	4.088	17.126
13.8	2.945	2.088	1.280	1.136	1.314	2.674	11.437
9.8	0.562	1.307	0.802	0.549	0.890	1.514	5.624
-8	<u>3.867</u>	<u>1.724</u>	<u>1.660</u>	<u>1.435</u>	<u>1.608</u>	<u>3.125</u>	<u>13.419</u>
SUM	51.648	32.627	22.731	19.953	21.640	74.562	223.161
ORIGINAL GMS. OF FROTH	52.872	33.780	22.964	20.502	22.202	75.527	227.847

FIG. 1 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 1-1

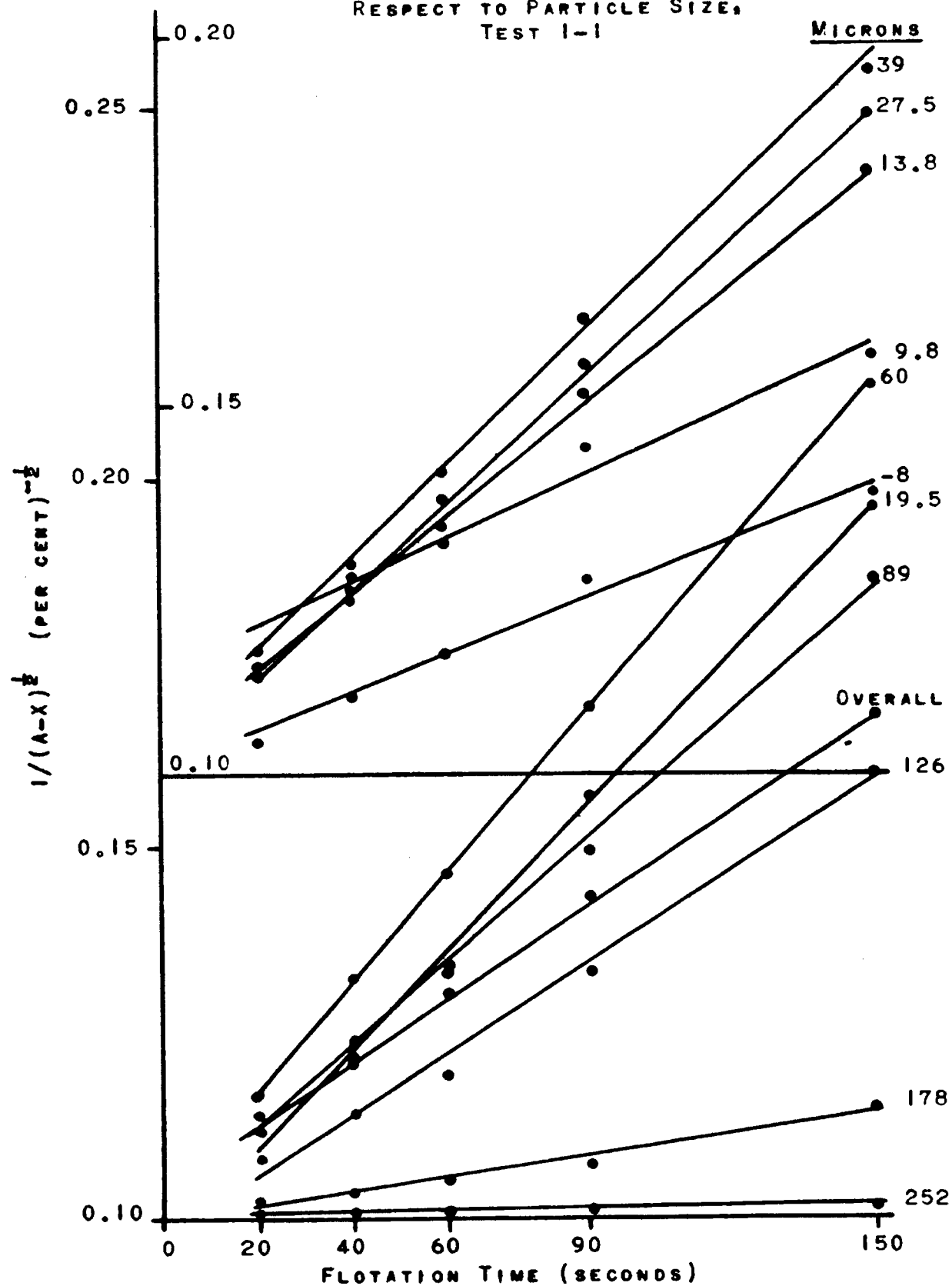


FIG. 2 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 1-2

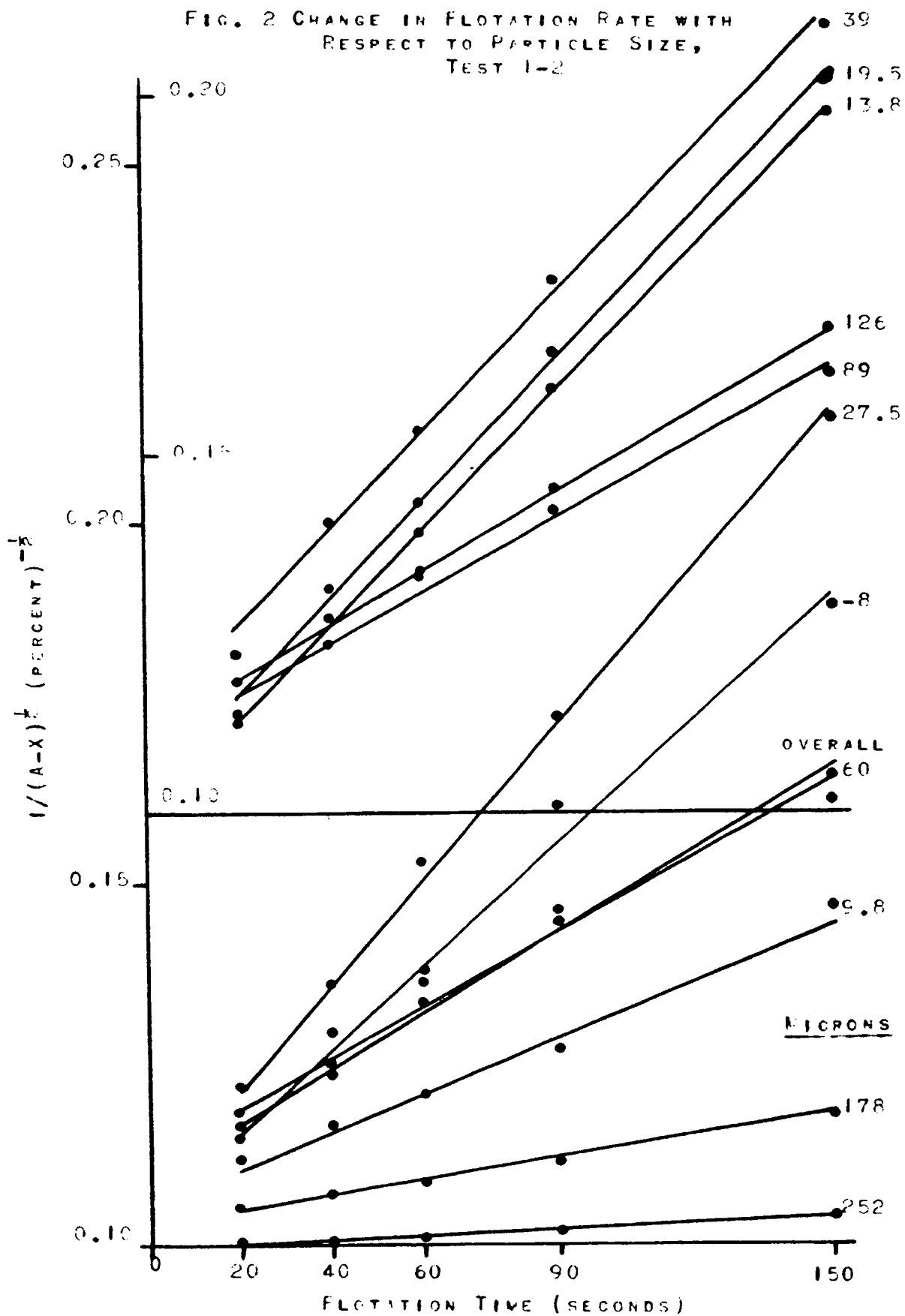
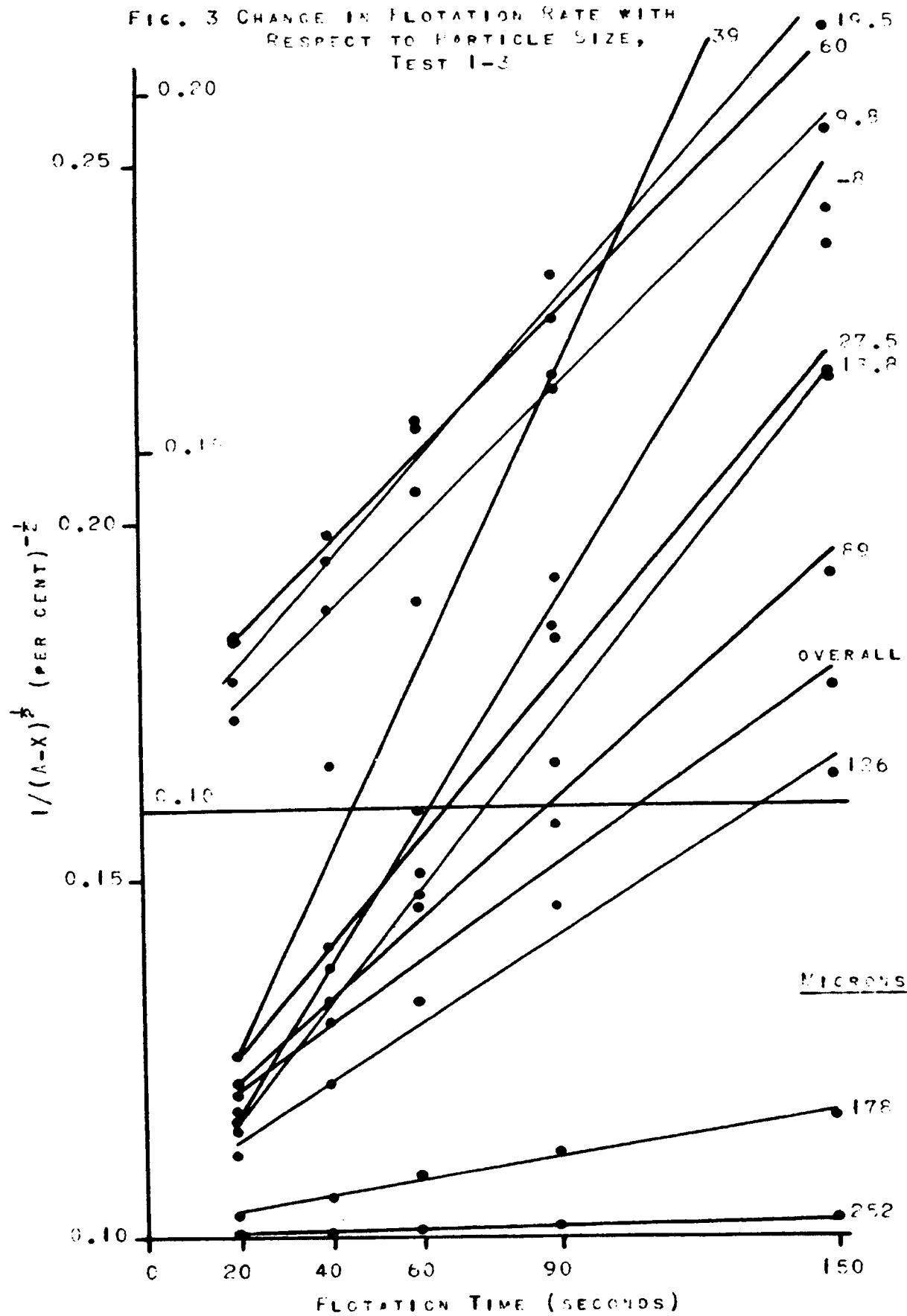
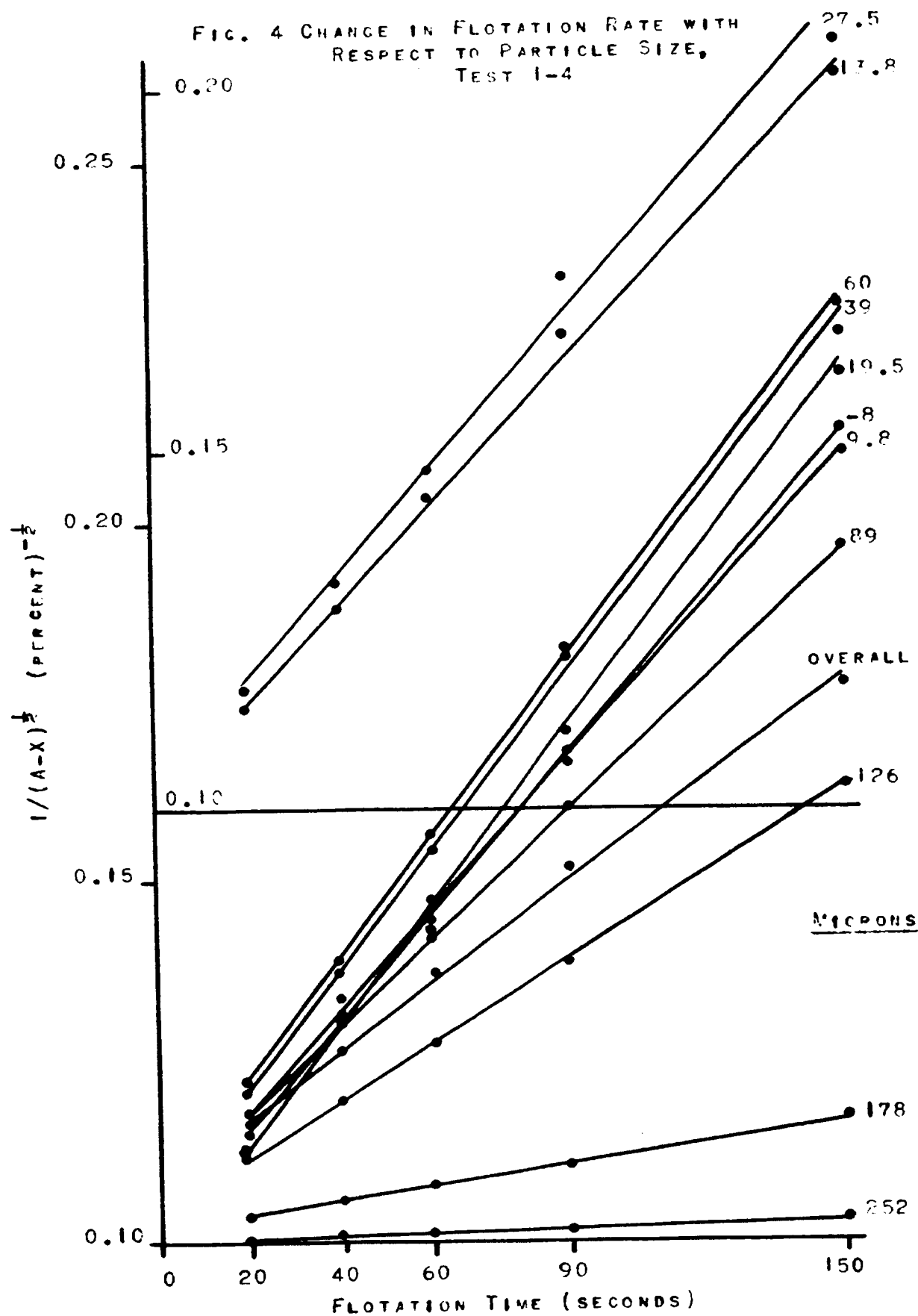
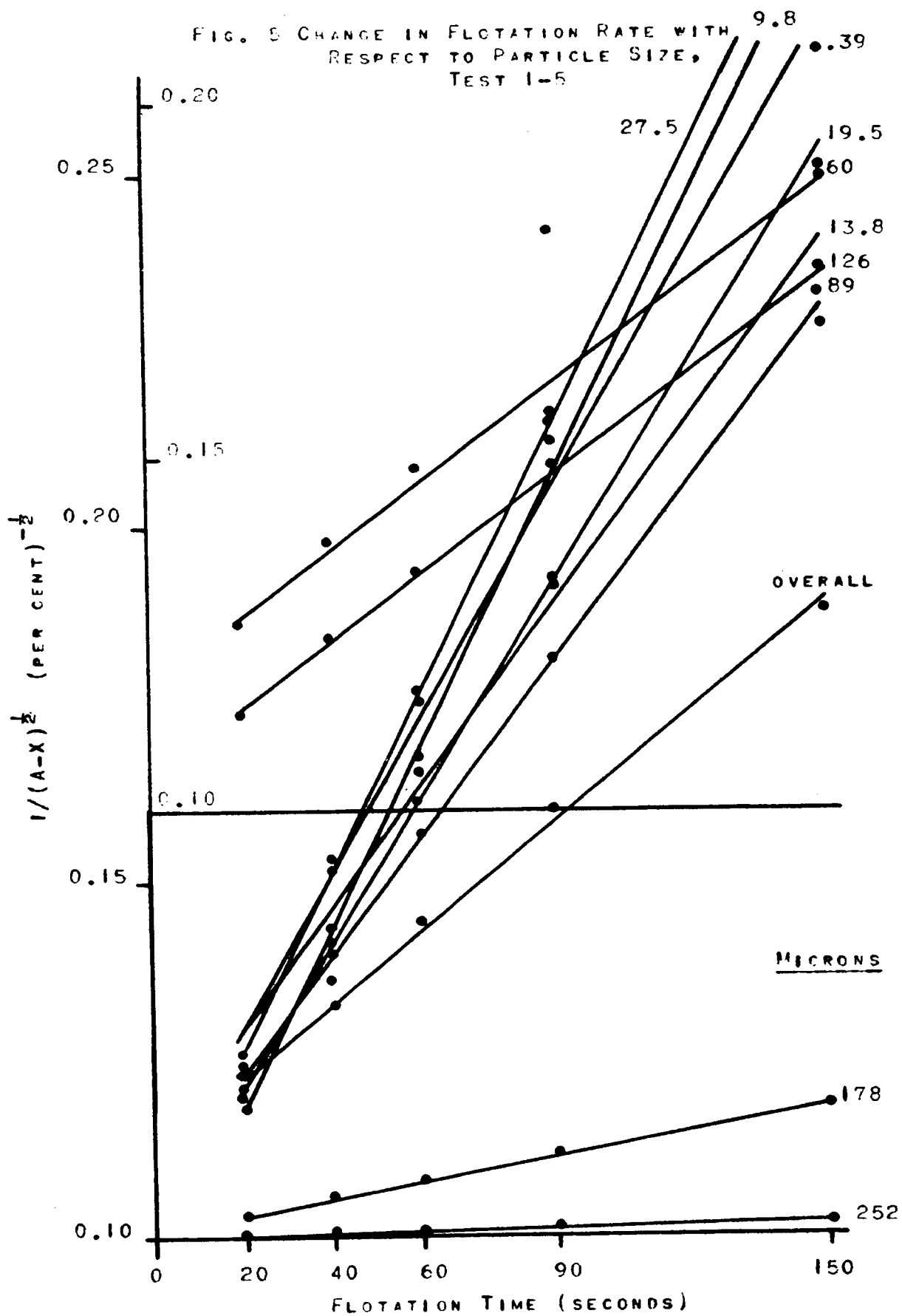
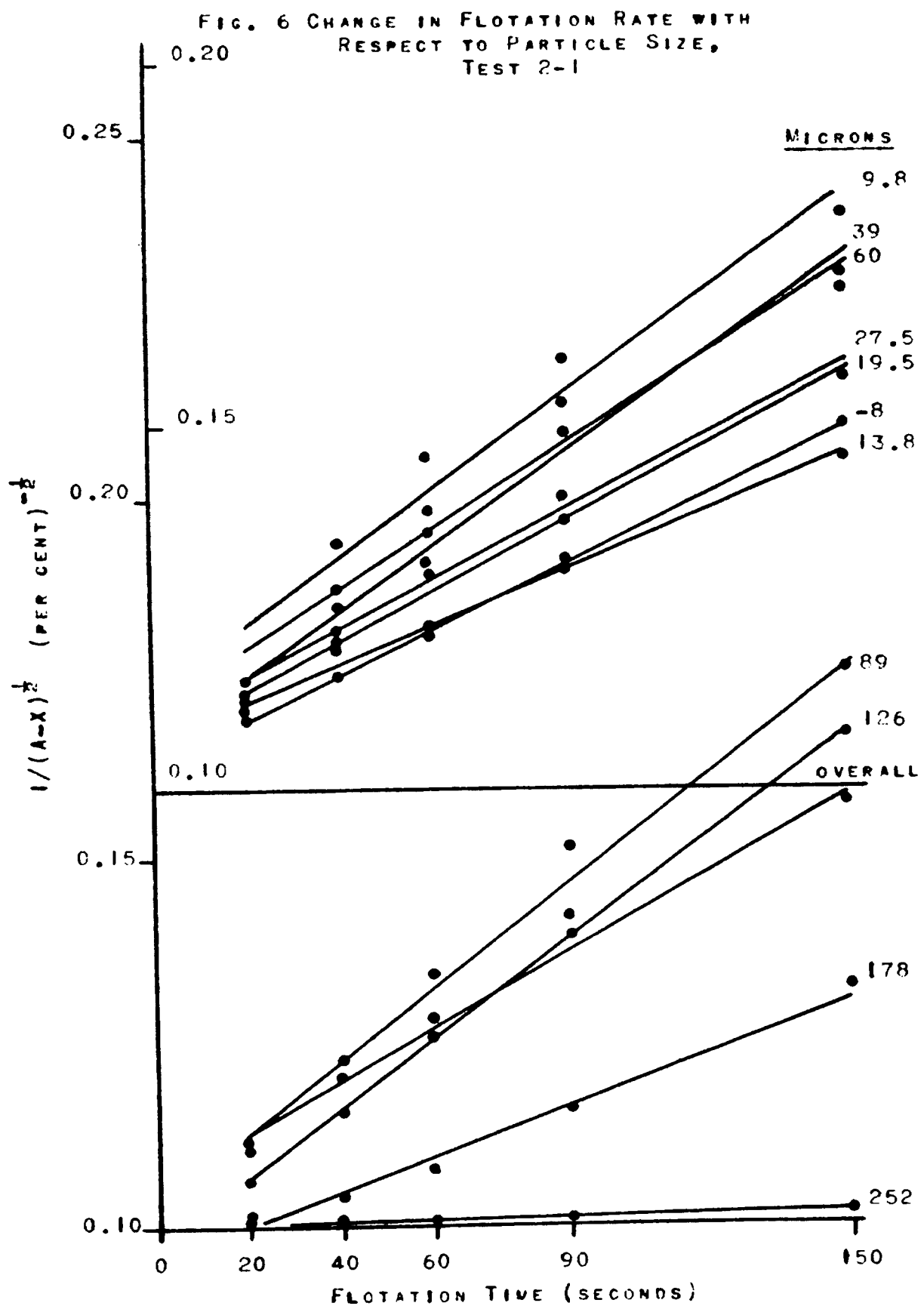


FIG. 3 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 1-3









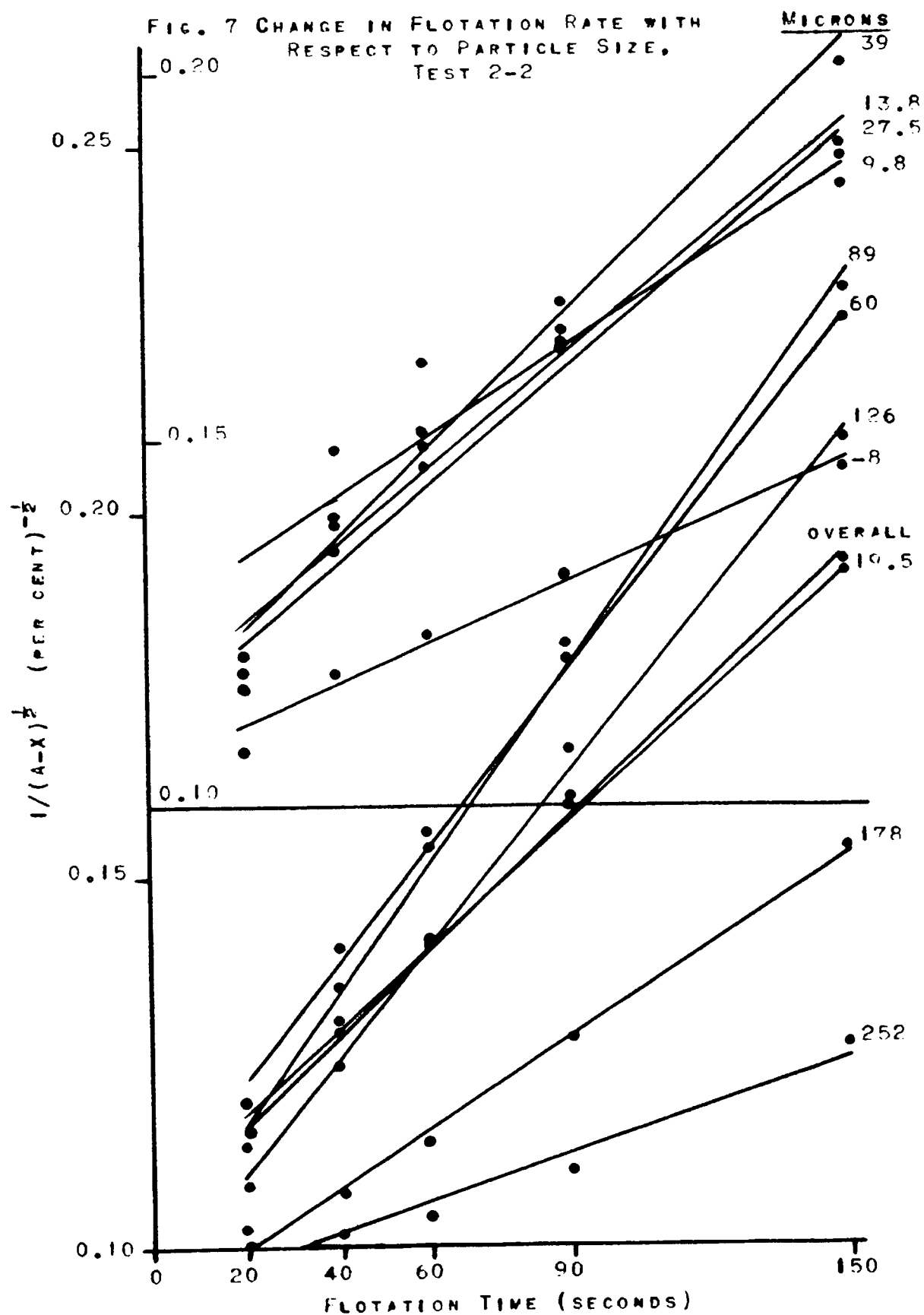
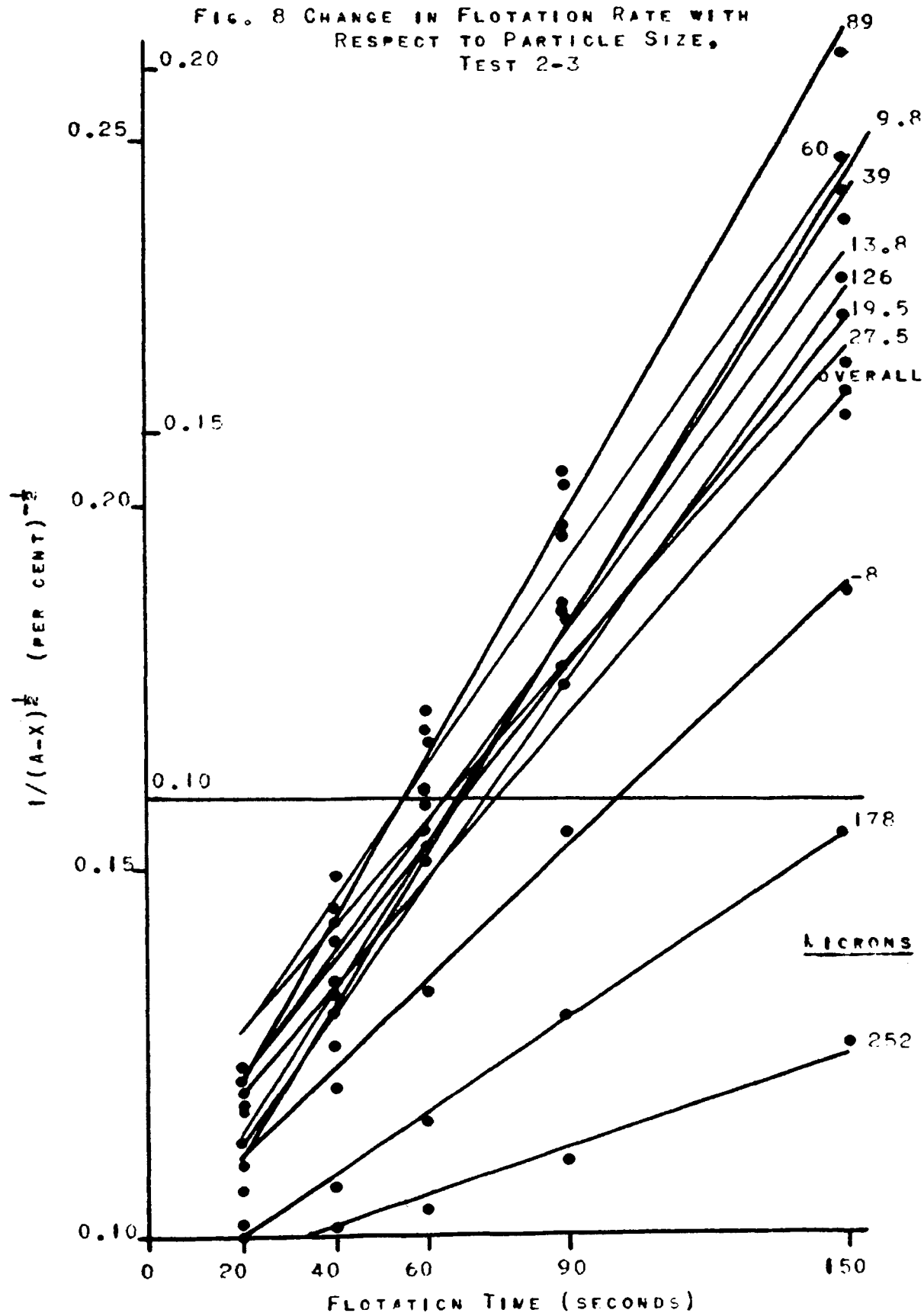
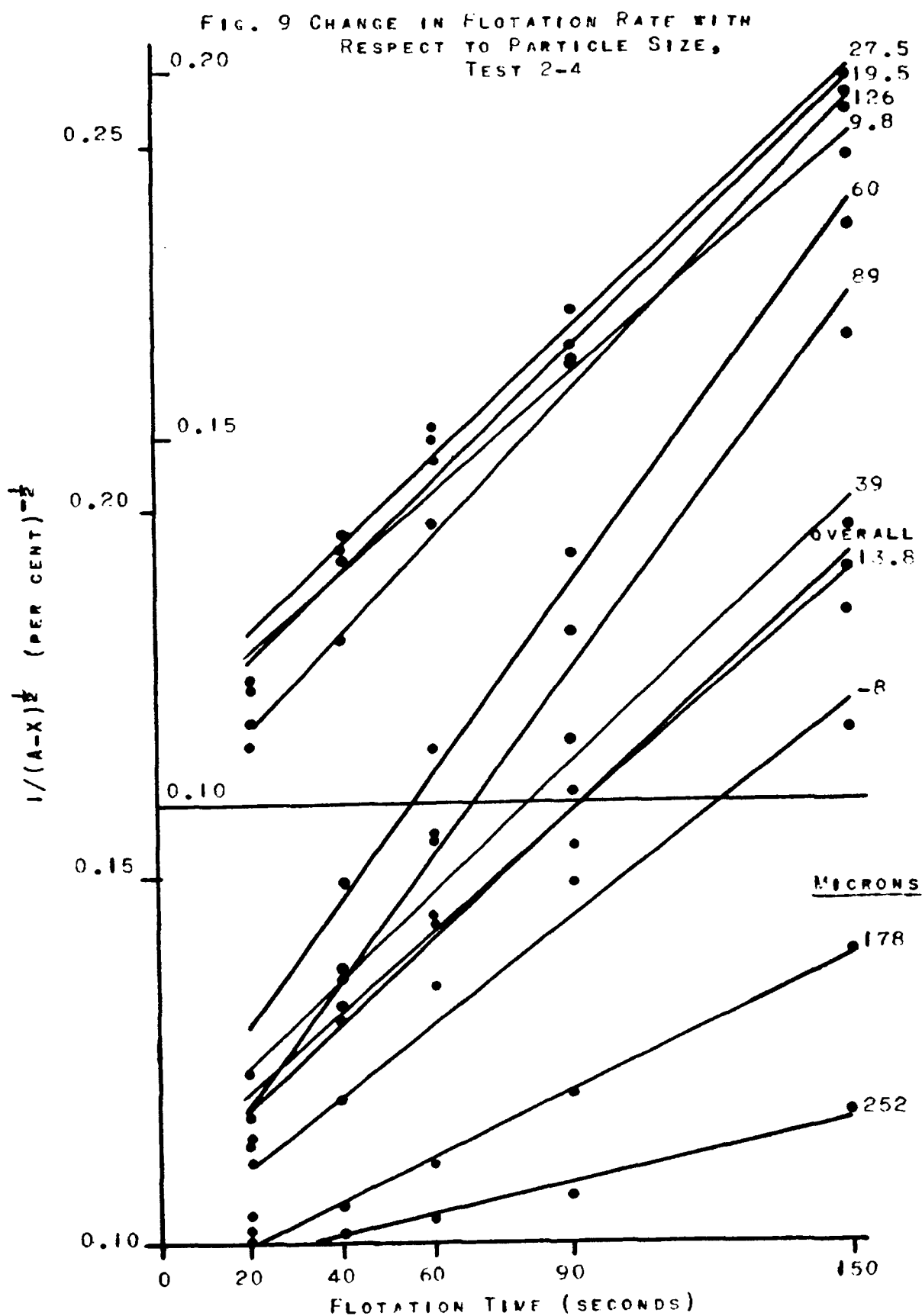
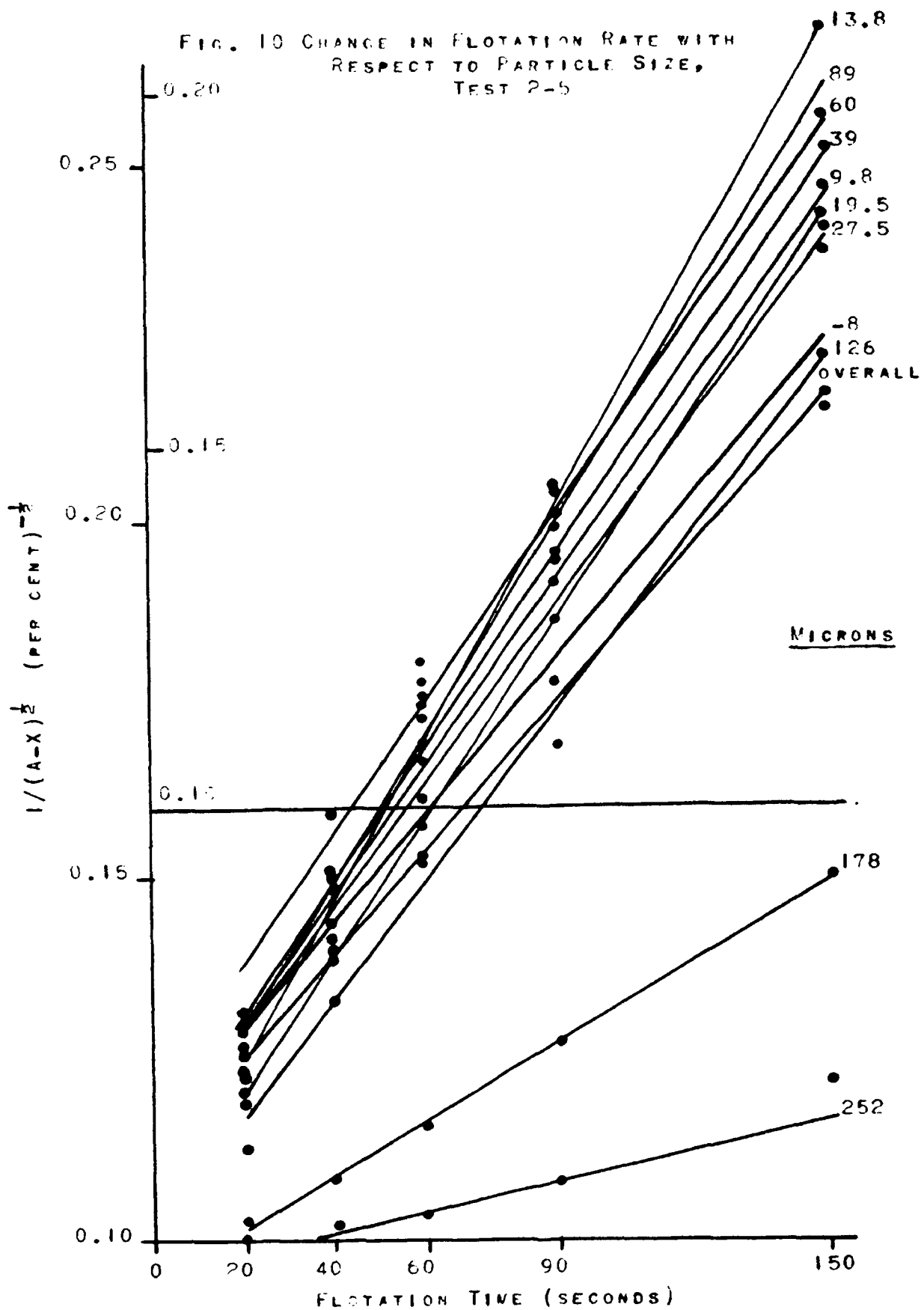


FIG. 8 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 2-3







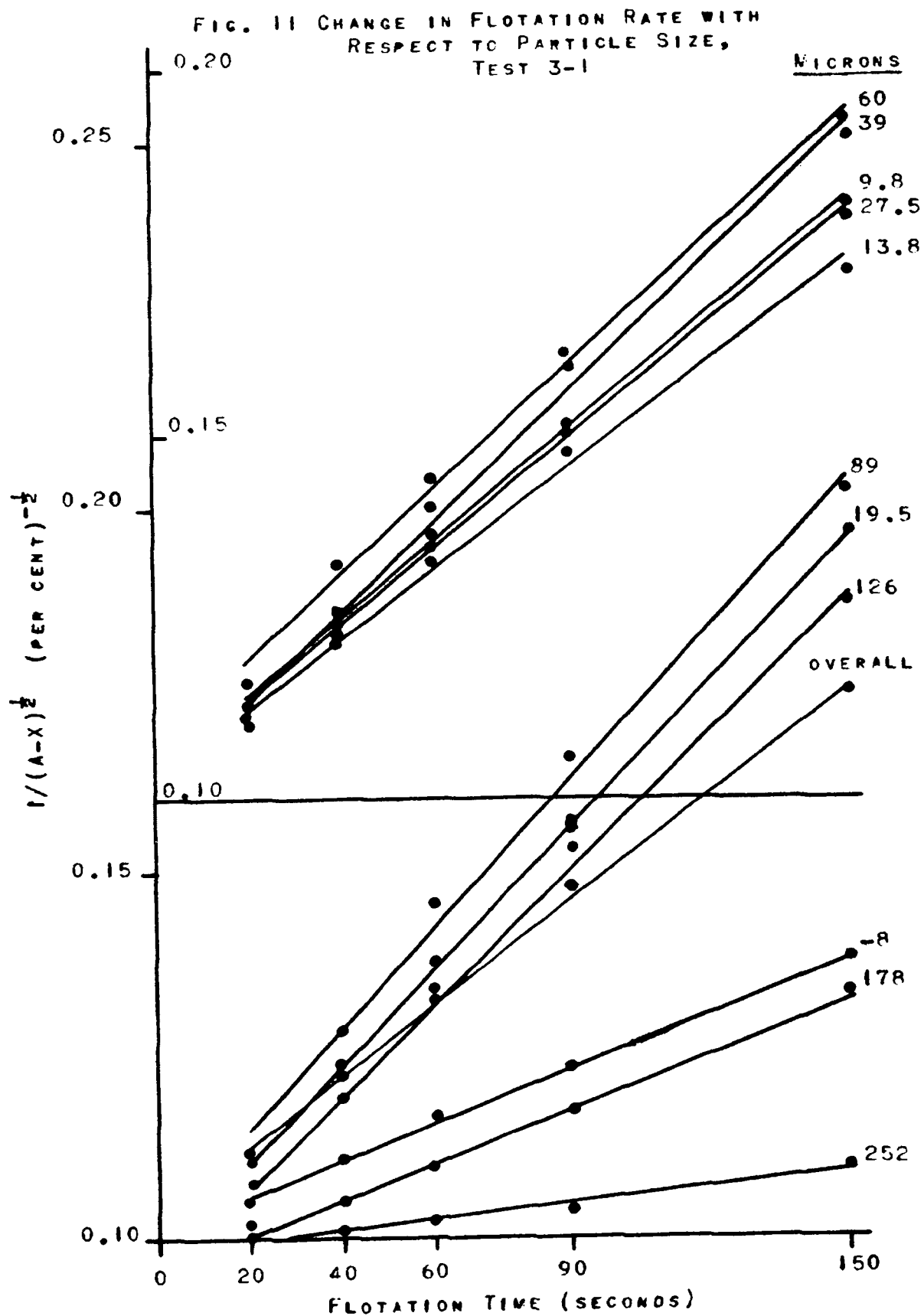
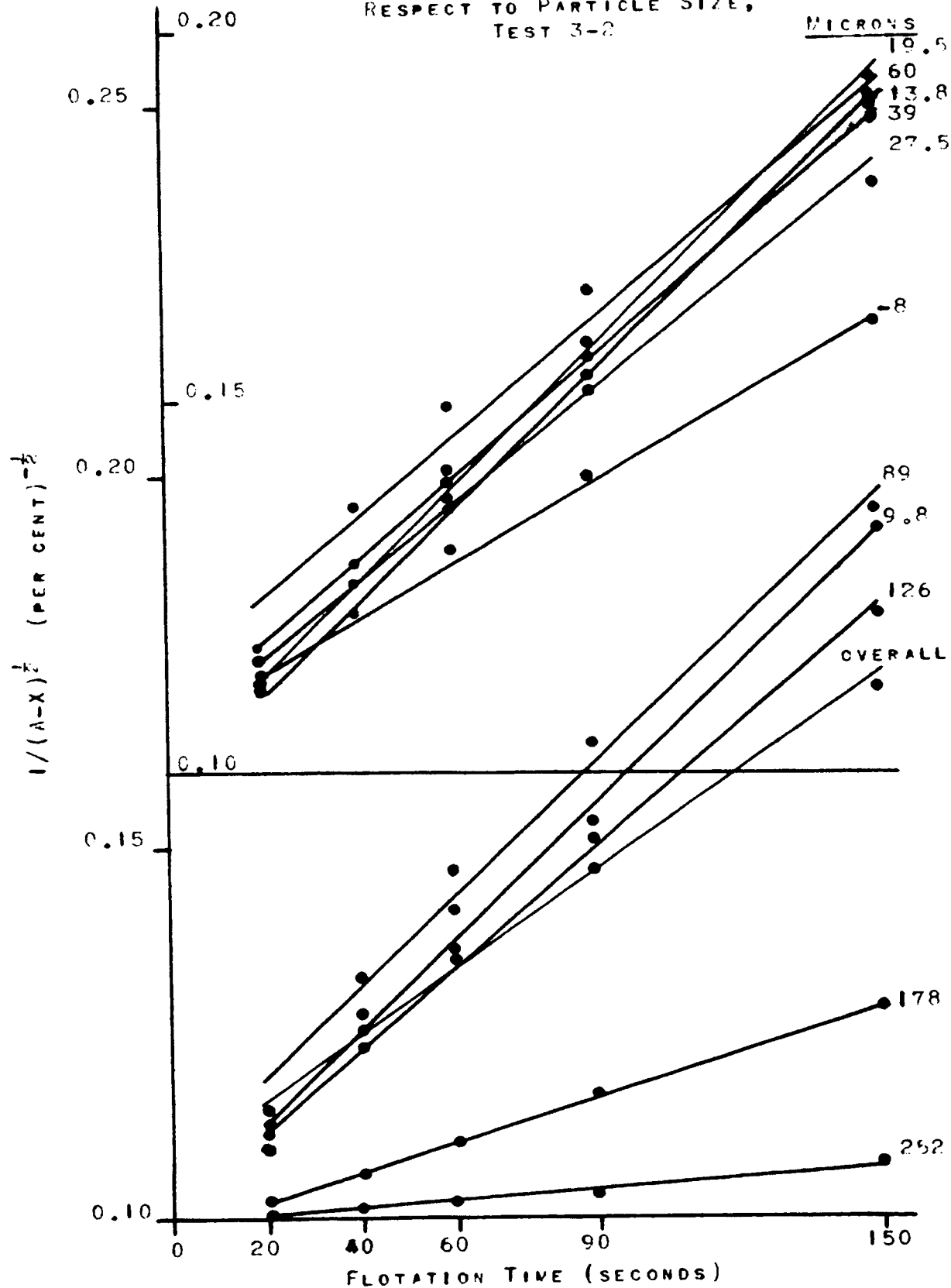
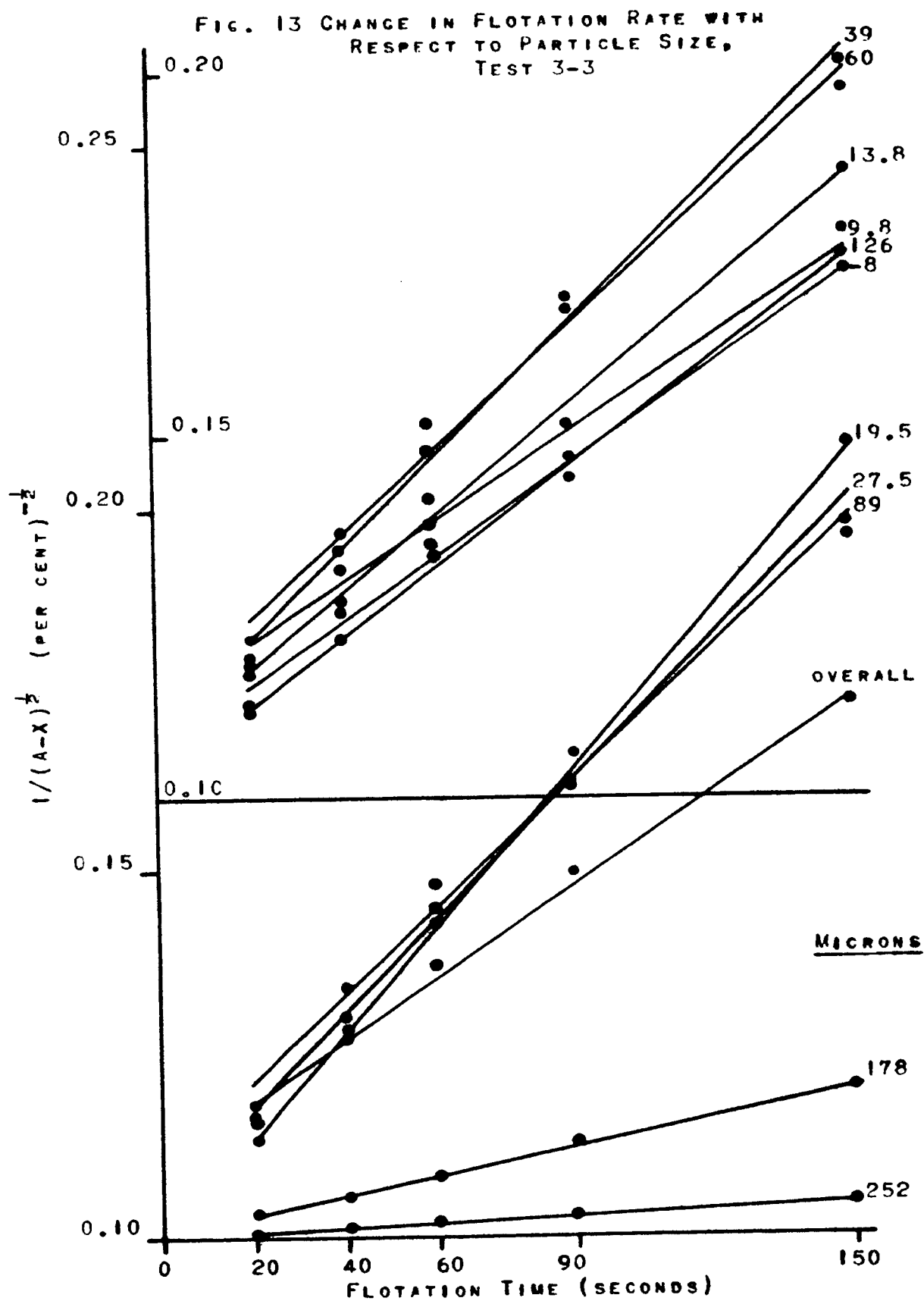
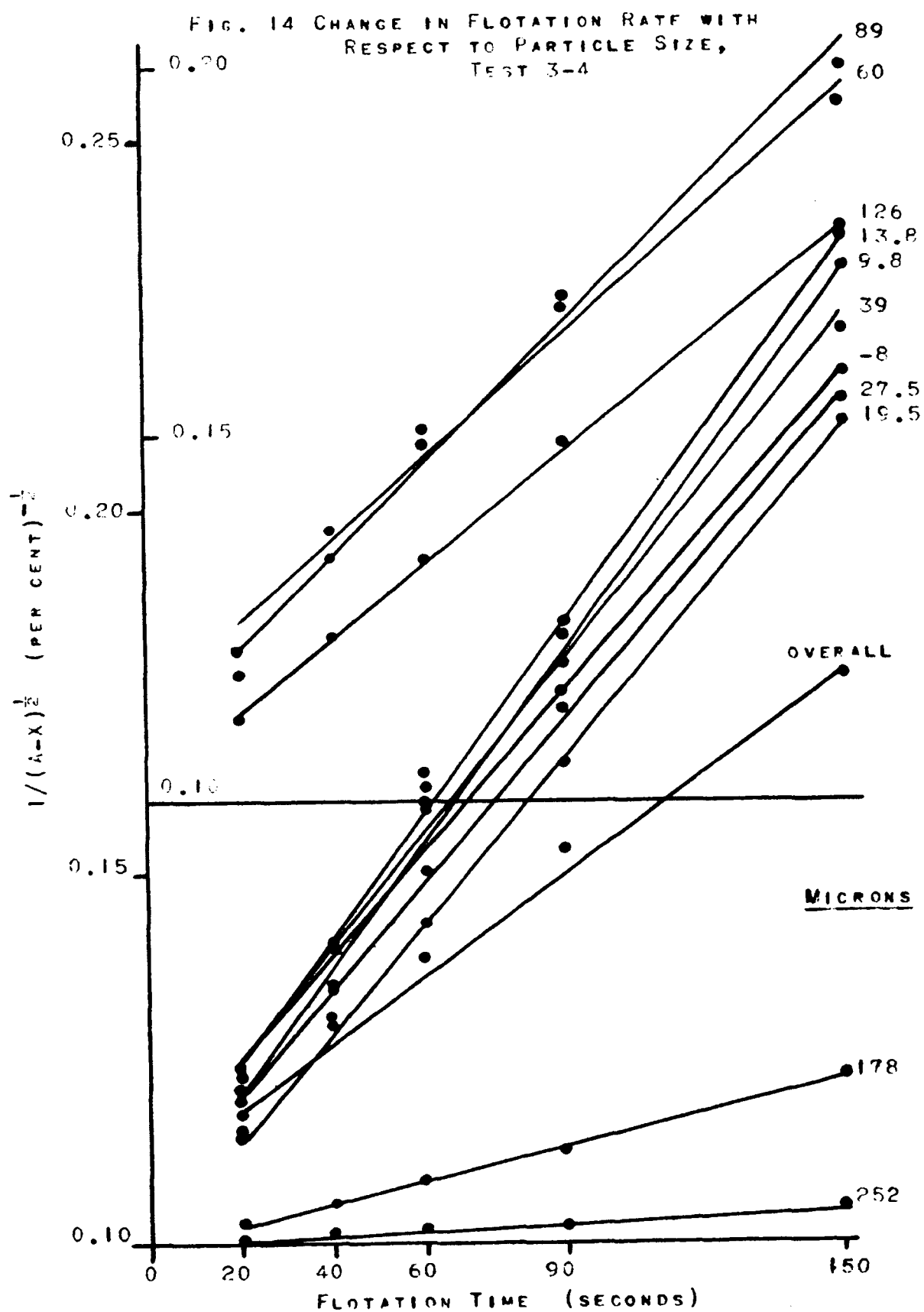


FIG. 12 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 3-2







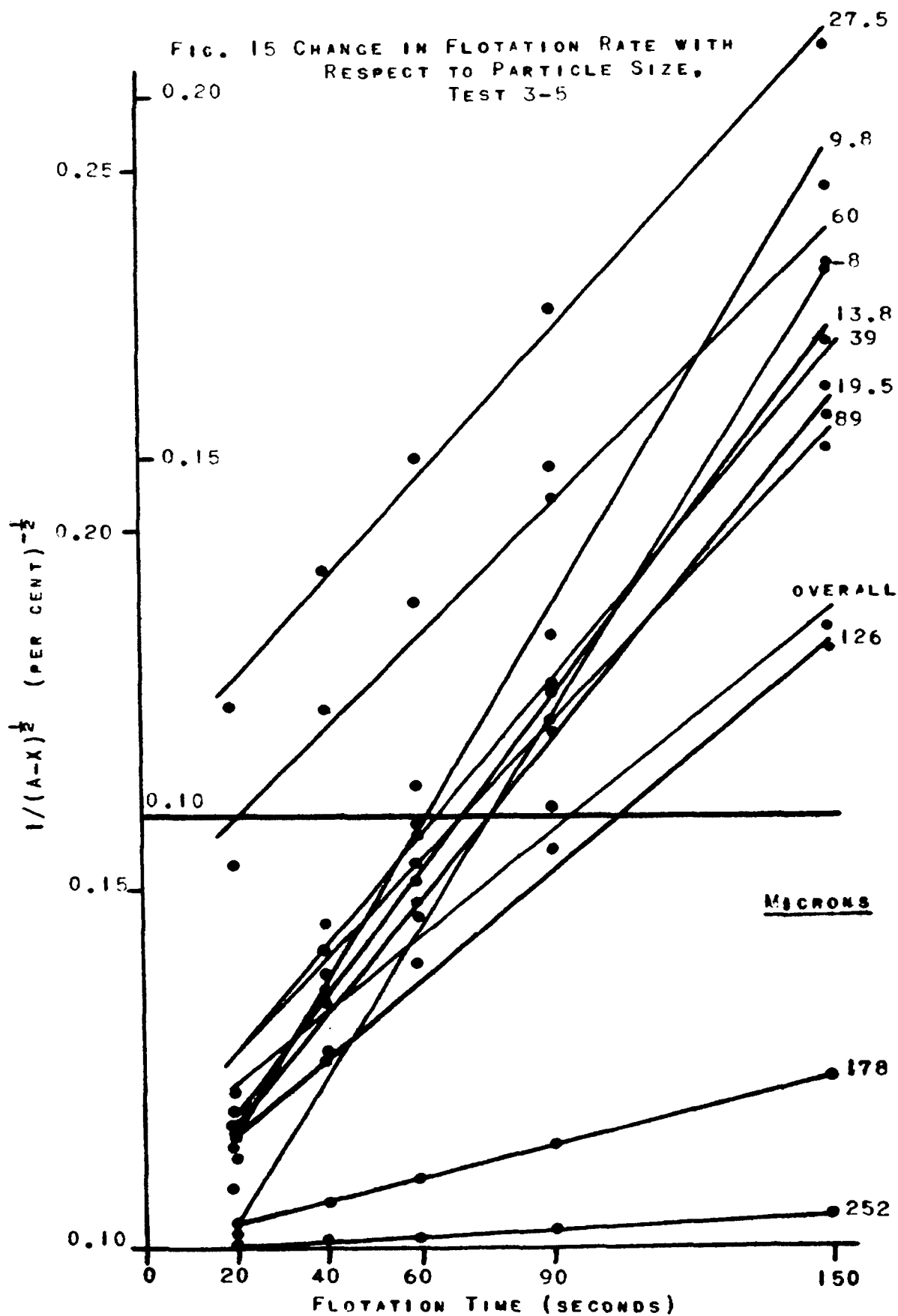


FIG. 16 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 4-1

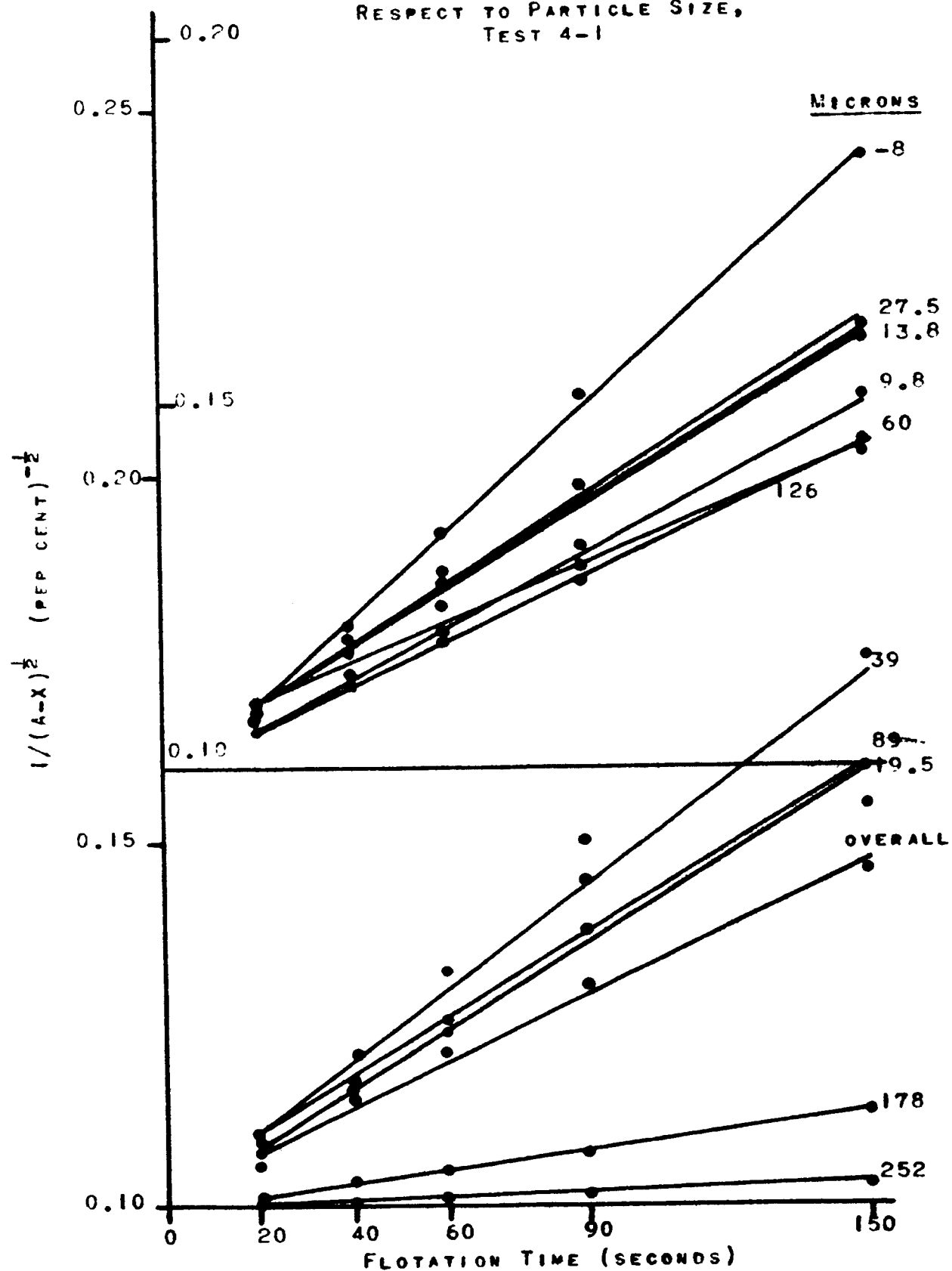


FIG. 17 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 4-2

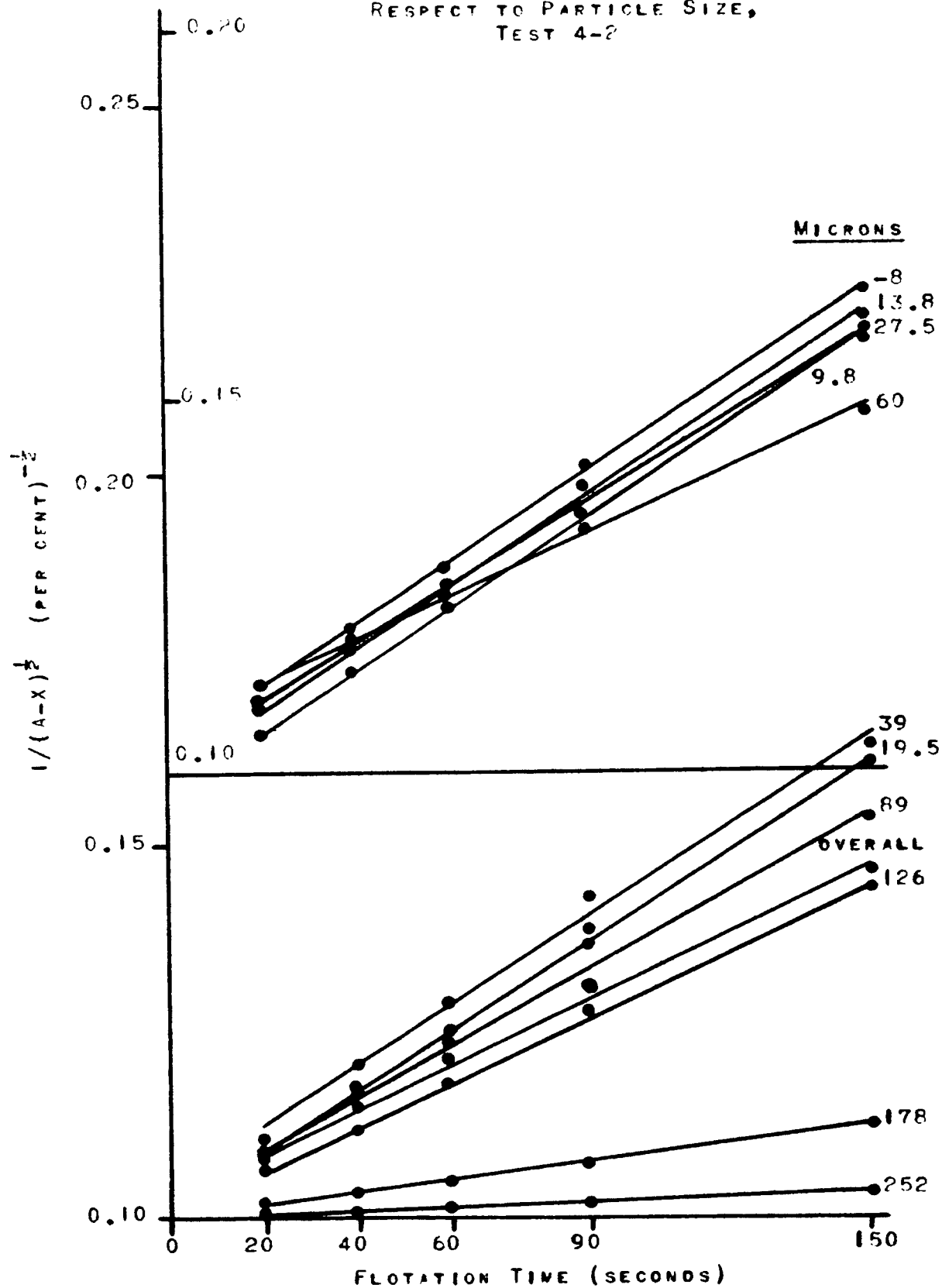


FIG. 18 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 4-3

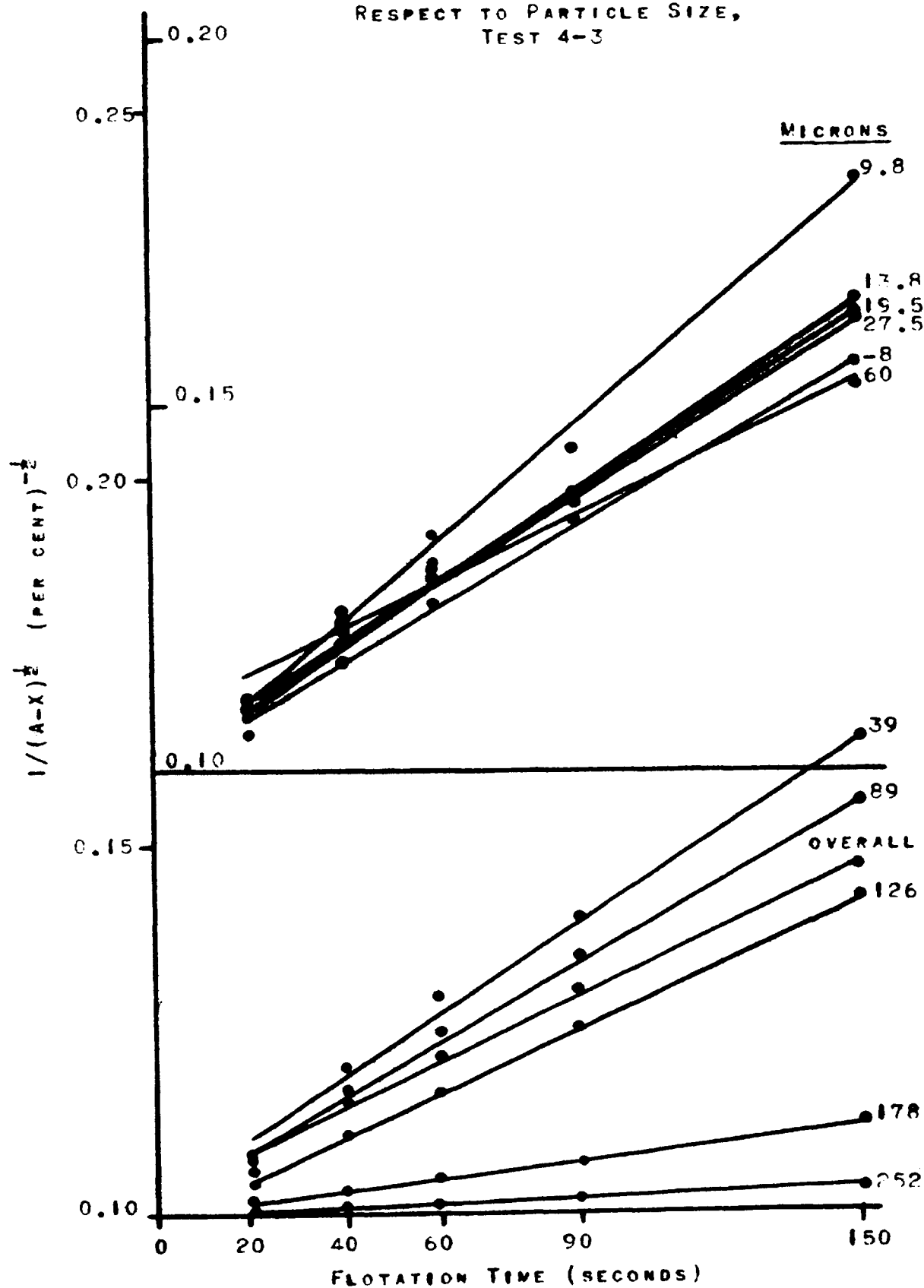
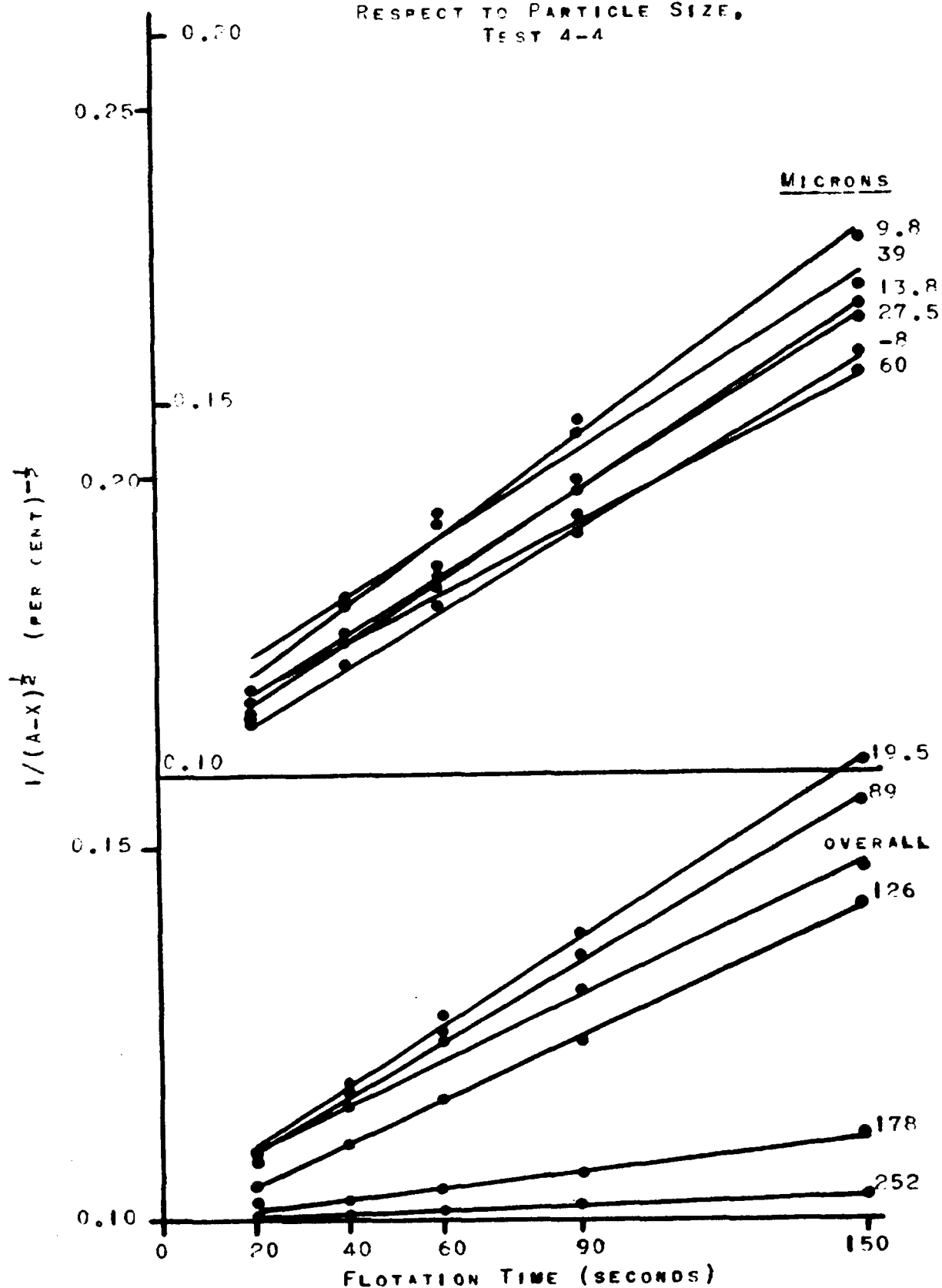


FIG. 19 CHANGE IN FLOTATION RATE WITH
RESPECT TO PARTICLE SIZE,
TEST 4-4



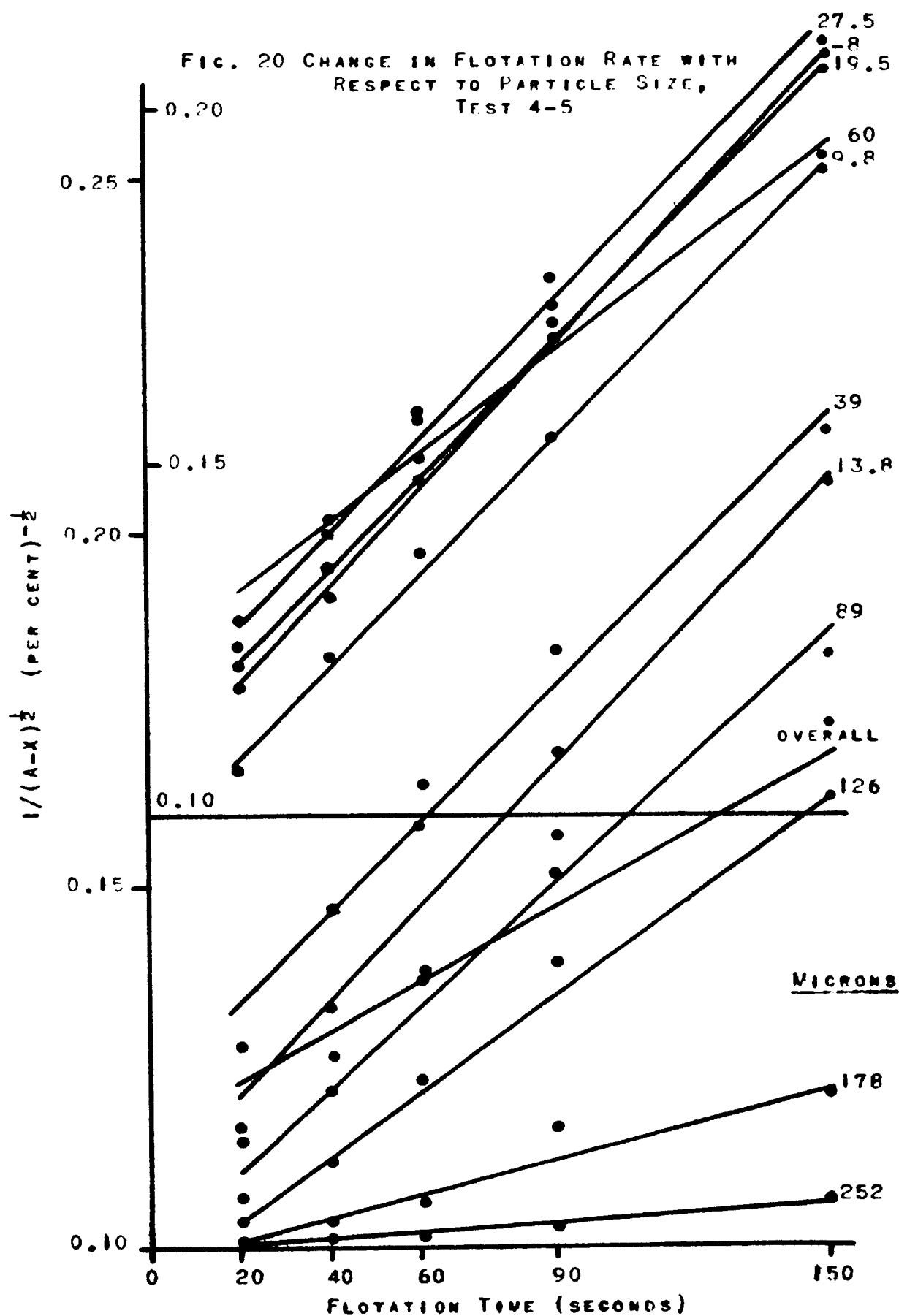


TABLE 31
CALCULATED FLOTATION RATE CONSTANTS

IMPELLER SPEED --- 863

FLOTATION RATE CONSTANT, K ($1/(\text{MIN.})(\text{PER CENT})^{\frac{1}{2}}$)

MEAN DIA. MICRONS	AIR VOLUME (LITERS PER MIN.)				
	1.0	2.0	2.5	3.0	3.5
OVERALL	0.0358	0.0354	0.0369	0.0361	0.0425
252	0.0026	0.0027	0.0028	0.0027	0.0056
178	0.0107	0.0100	0.0102	0.0097	0.0202
126	0.0369	0.0360	0.0356	0.0461	0.0677
89	0.0470	0.0423	0.0442	0.0444	0.0704
60	0.0323	0.0354	0.0391	0.0406	0.0589
39	0.0514	0.0487	0.0508	0.0490	0.0773
27.5	0.0480	0.0465	0.0484	0.0477	0.0798
19.5	0.0484	0.0491	0.0500	0.0487	0.0789
13.8	0.0477	0.0505	0.0518	0.0501	0.0826
9.8	0.0409	0.0501	0.0653	0.0561	0.0786
-8	0.0706	0.0501	0.0460	0.0445	0.0825

IMPELLER SPEED --- 1294

FLOTATION RATE CONSTANT, K ($1/(\text{MIN.})(\text{PER CENT})^{\frac{1}{2}}$)

MEAN DIA. MICRONS	AIR VOLUME (LITERS PER MIN.)				
	1.0	2.0	2.5	3.0	3.5
OVERALL	0.0580	0.0526	0.0516	0.0448	0.0608
252	0.0092	0.0059	0.0036	0.0040	0.0036
178	0.0301	0.0237	0.0160	0.0188	0.0188
126	0.0744	0.0650	0.0581	0.0616	0.0638
89	0.0826	0.0720	0.0713	0.0765	0.0800
60	0.0700	0.0646	0.0703	0.0679	0.0755
39	0.0738	0.0663	0.0755	0.0945	0.0901
27.5	0.0634	0.0600	0.0756	0.0893	0.0839
19.5	0.0797	0.0749	0.0878	0.0941	0.0917
13.8	0.0573	0.0744	0.0630	0.105	0.101
9.8	0.0638	0.0731	0.0496	0.105	0.129
-8	0.0303	0.0448	0.0531	0.0768	0.122

TABLE 32
CALCULATED FLOTATION RATE CONSTANTS
IMPELLER SPEED --- 1725 RPM

FLOTATION RATE CONSTANT, K (1/(MIN.))(PER CENT) ^{$\frac{1}{2}$}					
MEAN DIA.	AIR VOLUME (LITERS PER MIN.)				
MICRONS	1.0	2.0	2.5	3.0	3.5
OVERALL	0.0519	0.0458	0.0547	0.0565	0.0624
252	0.0014	0.0035	0.0018	0.0024	0.0016
178	0.0116	0.0118	0.0130	0.0127	0.0138
126	0.0491	0.0444	0.0491	0.0472	0.0571
89	0.0675	0.0424	0.0686	0.0721	0.101
60	0.0884	0.0465	0.0383	0.101	0.0567
39	0.0737	0.0797	0.164	0.0928	0.132
27.5	0.0712	0.0878	0.0917	0.0868	0.127
19.5	0.0802	0.0802	0.0851	0.104	0.112
13.8	0.0622	0.0776	0.0972	0.0825	0.103
9.8	0.0350	0.0361	0.0753	0.0870	0.155
-8	0.0311	0.0724	0.143	0.0902	0.340

IMPELLER SPEED --- 2048

FLOTATION RATE CONSTANT, K (1/(MIN.))(PER CENT) ^{$\frac{1}{2}$}					
MEAN DIA.	AIR VOLUME (LITERS PER MIN.)				
MICRONS	1.0	2.0	2.5	3.0	3.5
OVERALL	0.0432	0.0721	0.0878	0.0698	0.0859
252	0.0148	0.0259	0.0251	0.0168	0.0198
178	0.0301	0.0498	0.0505	0.0367	0.0445
126	0.0579	0.0945	0.109	0.0811	0.0964
89	0.0610	0.107	0.133	0.101	0.121
60	0.0494	0.0970	0.109	0.104	0.108
39	0.0525	0.0738	0.105	0.0712	0.110
27.5	0.0404	0.0649	0.0865	0.0719	0.102
19.5	0.0411	0.0704	0.0950	0.0741	0.113
13.8	0.0320	0.0627	0.104	0.0564	0.134
9.8	0.0560	0.0514	0.123	0.0656	0.106
-8	0.0340	0.0342	0.0719	0.0588	0.0888

FIG. 21 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE,
AIR VOLUME CONSTANT (1.0 LITERS PER MIN.)

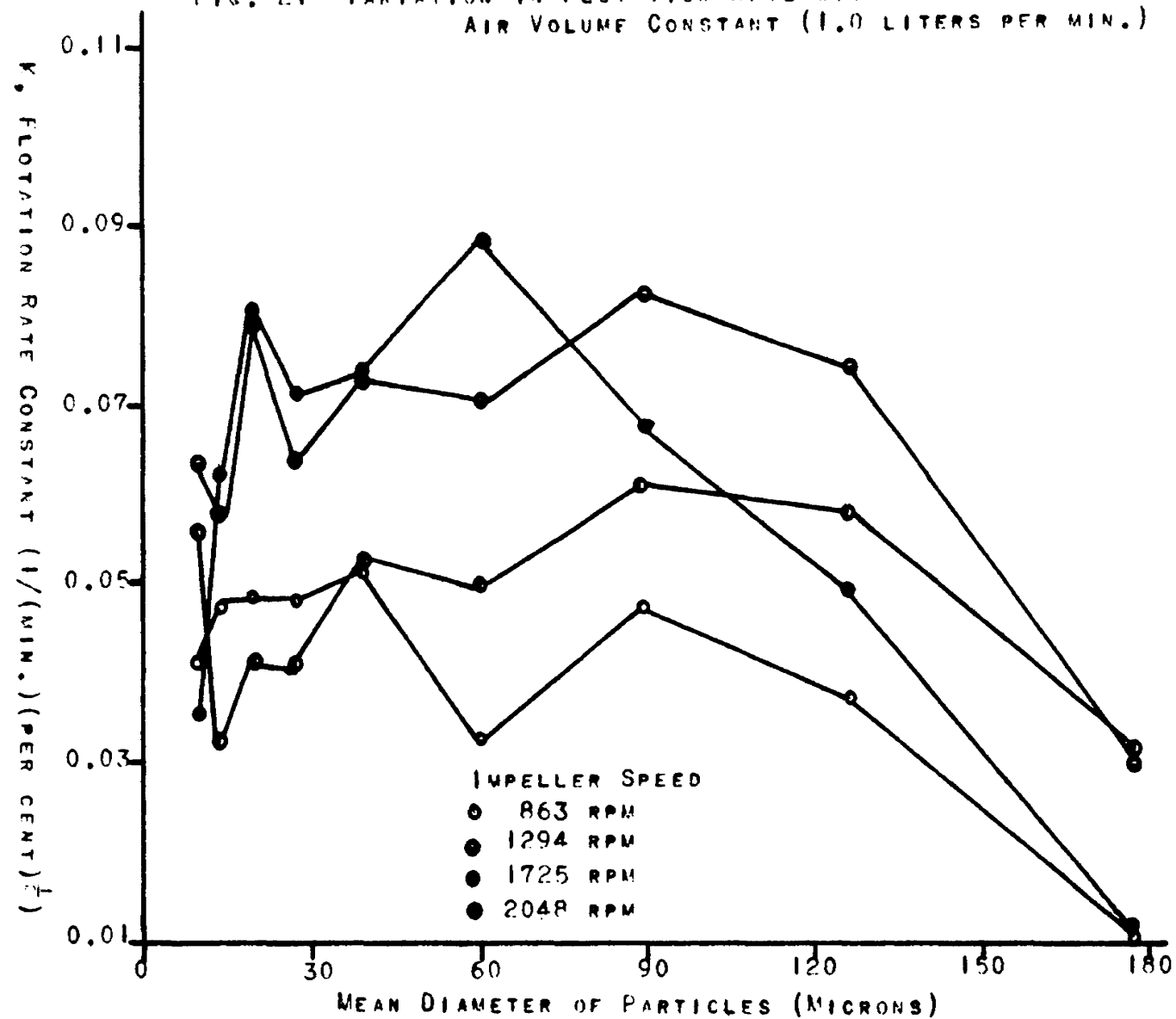


FIG. 22 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE,
AIR VOLUME CONSTANT (2.0 LITERS/MIN.)

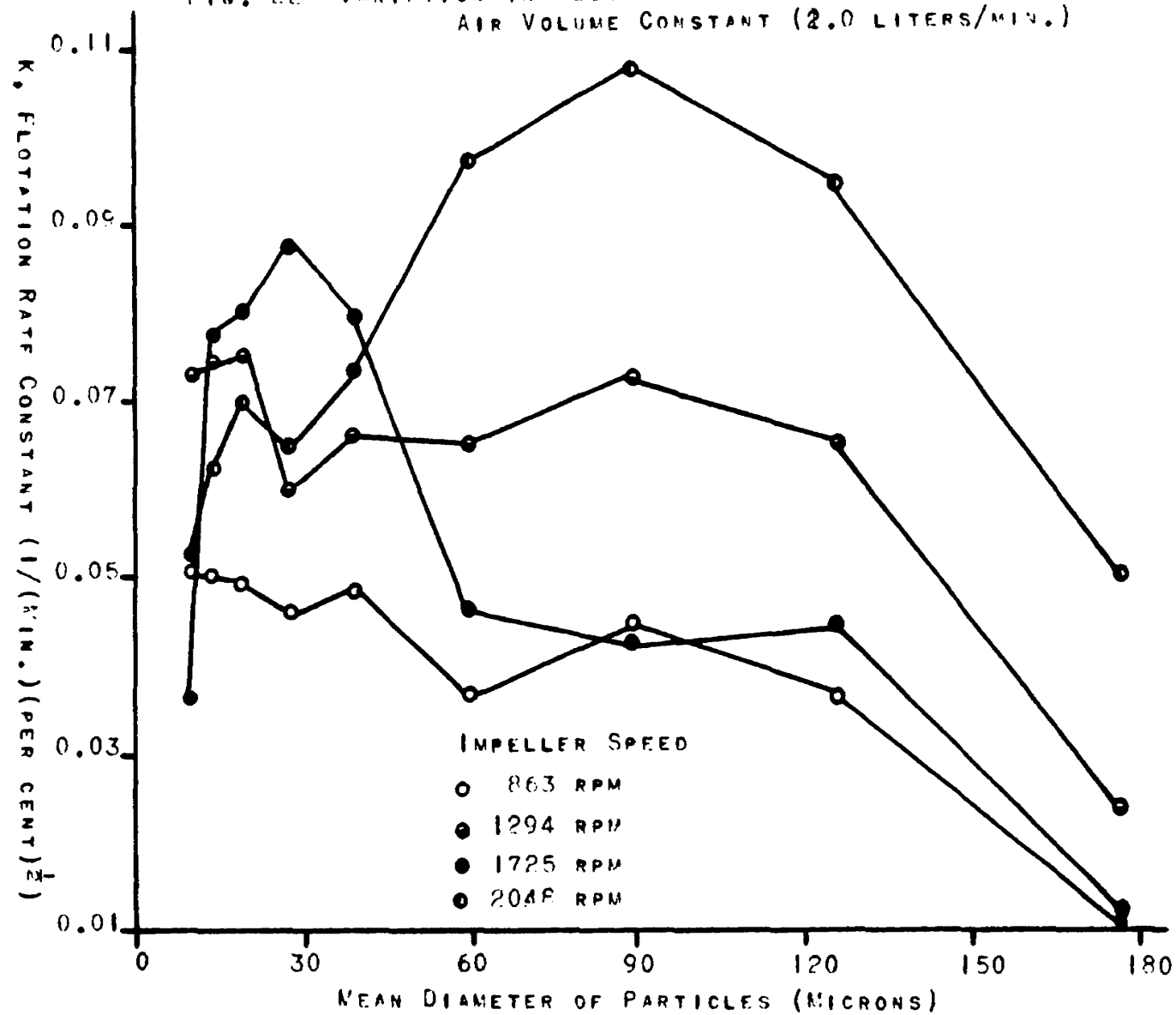


FIG. 23 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE,
AIR VOLUME CONSTANT (3.0 LITERS PER MIN.)

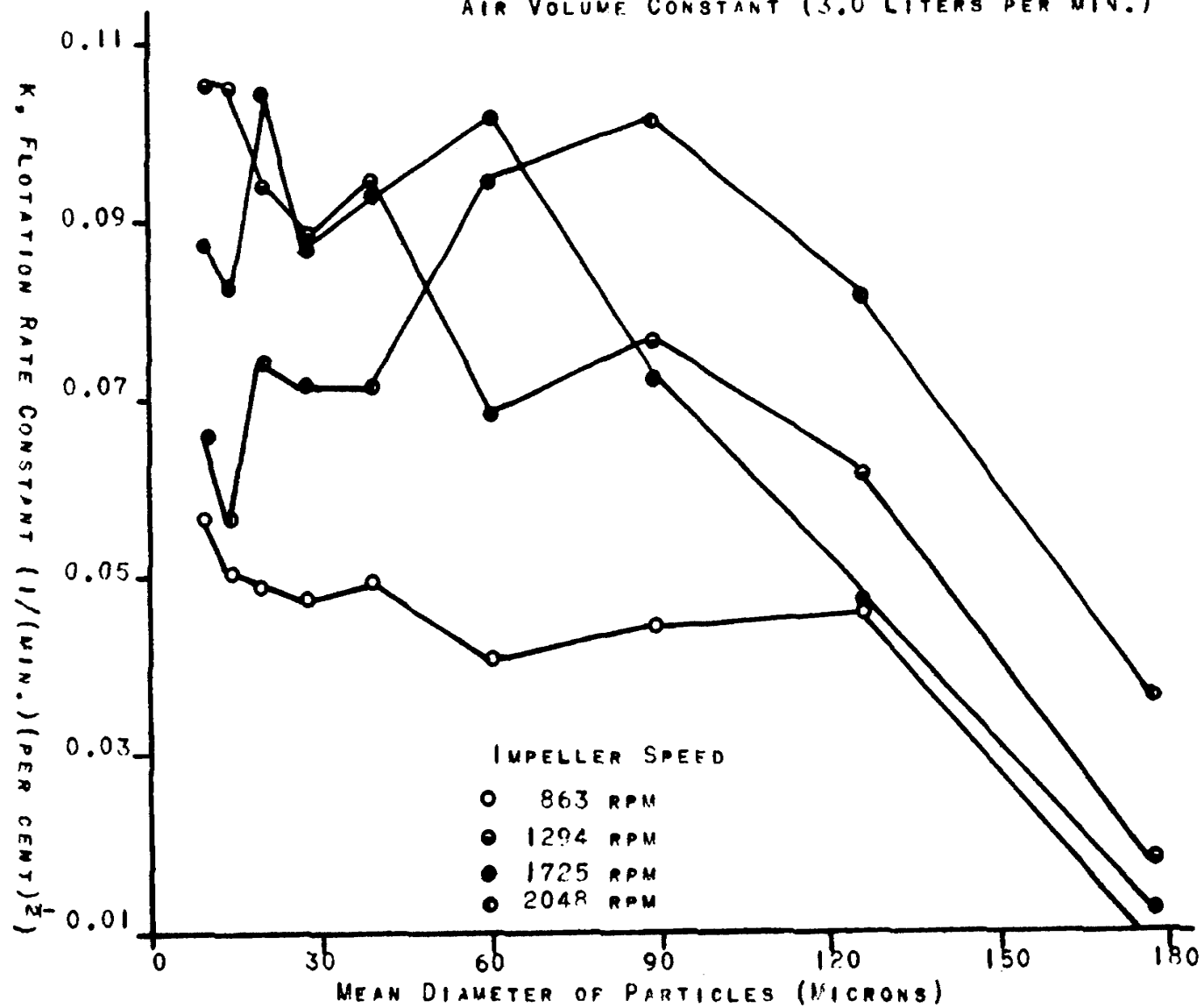


FIG. 24 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE,
IMPELLER SPEED CONSTANT (863 RPM)

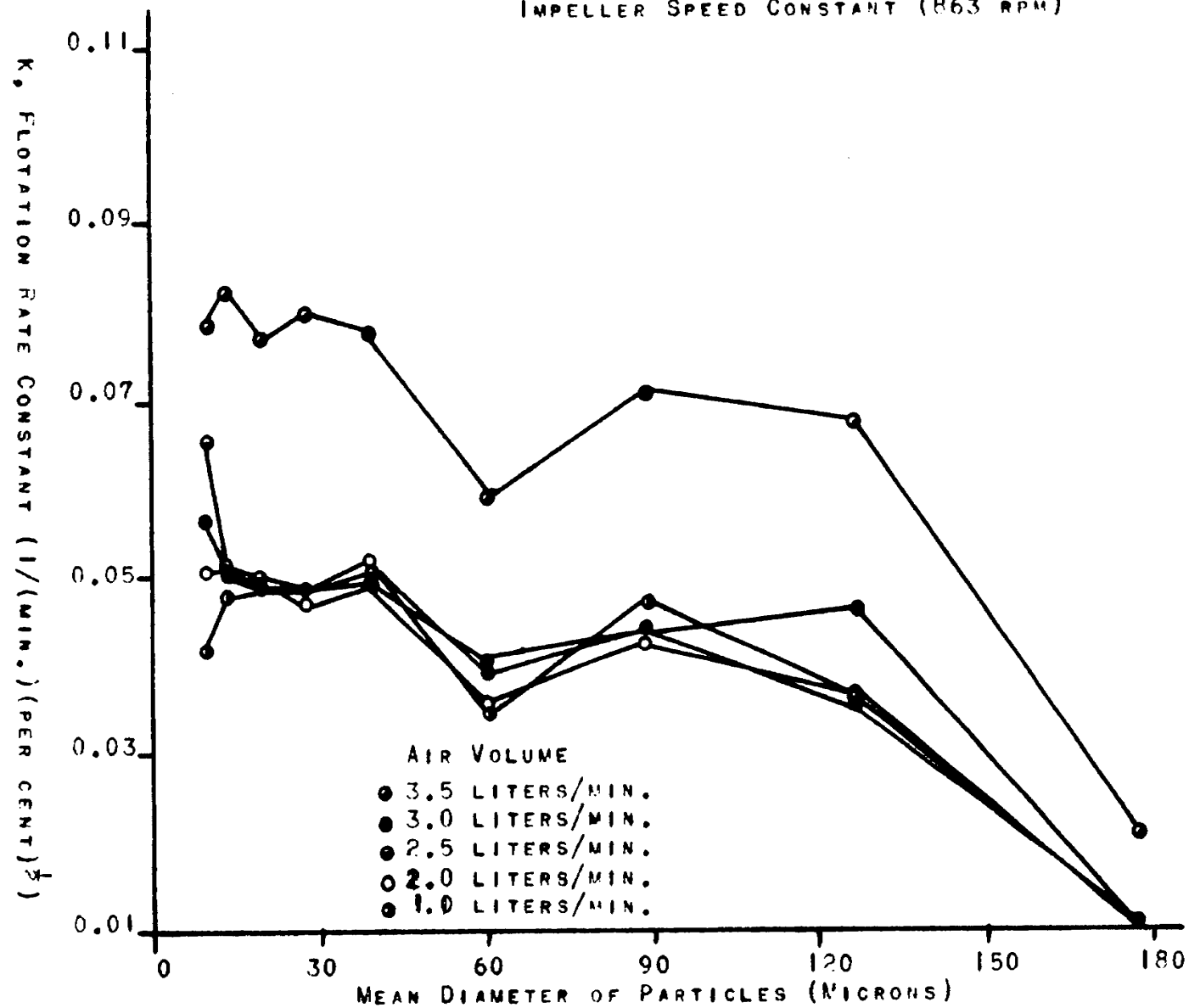


FIG. 25 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE,
IMPELLER SPEED CONSTANT (1294 RPM)

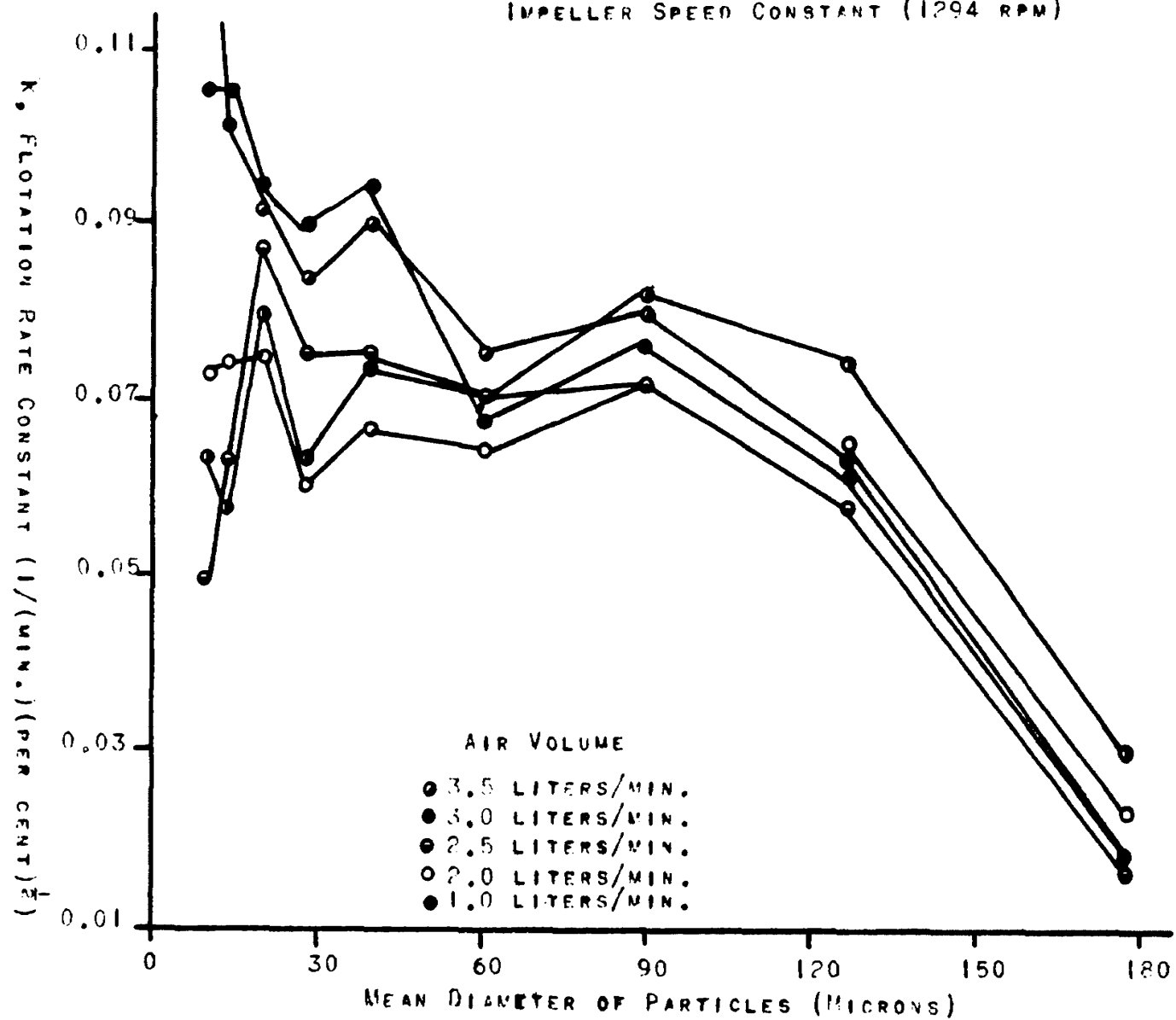
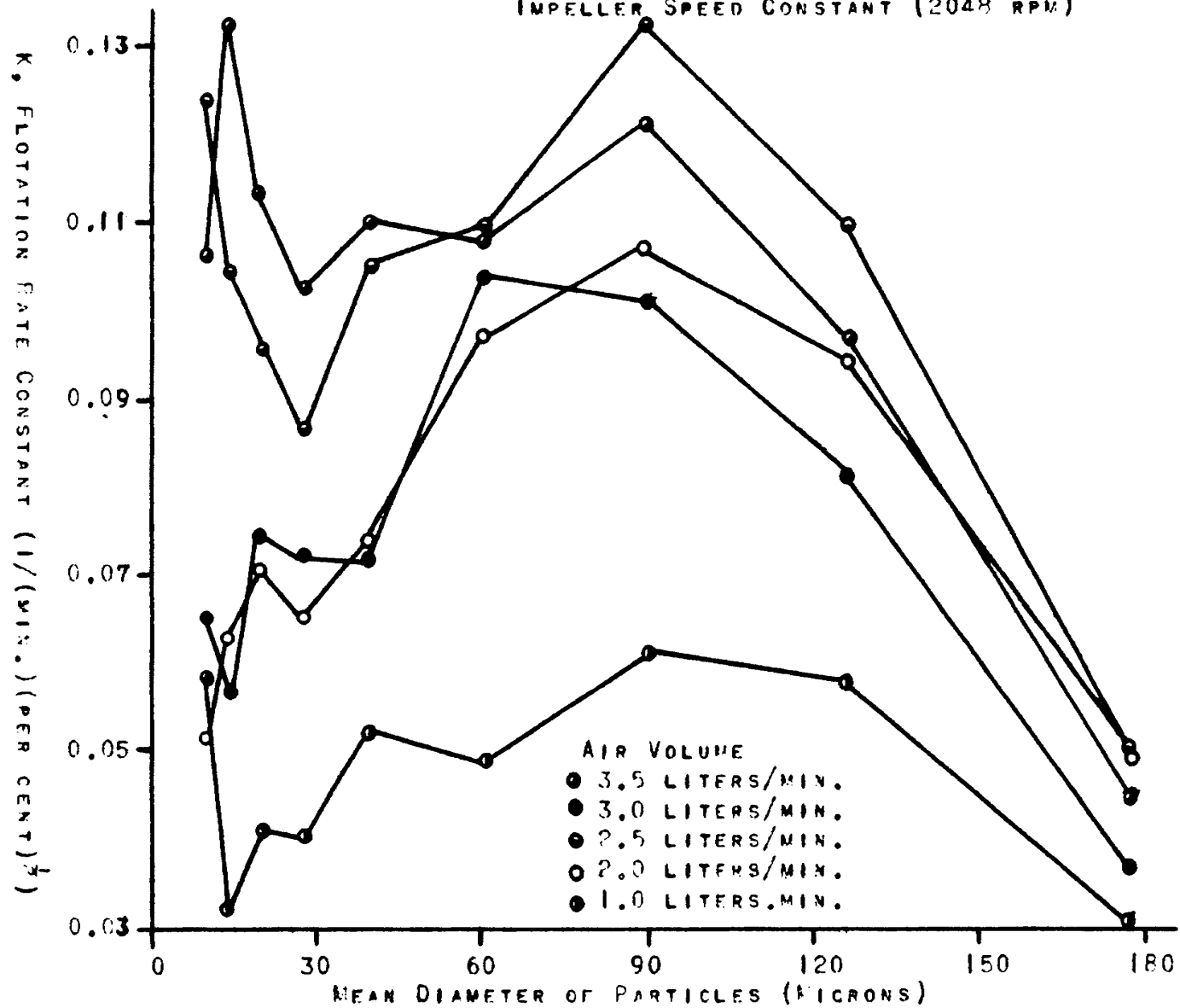


FIG. 26 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE,
IMPELLER SPEED CONSTANT (2048 RPM)



DISCUSSION OF RESULTS

TWO OF THE VARIABLES THAT AFFECT THE FLOTATION RATE WERE CONSIDERED IN THE INVESTIGATION. THESE VARIABLES WERE IMPELLER SPEED AND VOLUME OF AIR ENTERING THE FLOTATION CELL PER UNIT TIME.

MORRIS⁽¹⁴⁾ FOUND THAT THE FLOTATION RATE INCREASES

(14) MORRIS, T. M., OP. CIT.

AS THE PARTICLE SIZE INCREASES UNTIL A MAXIMUM RATE IS REACHED. THE MAXIMUM RATE OCCURED IN THE 50 TO 60 MICRON RANGE FOR COPPER AND PYRITE. AFTER THE MAXIMUM RATE WAS REACHED, THE FLOTATION RATE DECREASED WITH AN INCREASE IN PARTICLE SIZE.

KIDD AND WALL⁽¹⁵⁾ FLOATED VARIOUS SIZE FRACTIONS OF

(15) KIDD, R. L., AND WALL, W. L., EFFECT OF PARTICLE SIZE ON FLOTATION OF SPHALERITE: MINING AND METALLURGY, VOL. 14, PP. 421-422, 1933.

SPHALERITE AND PLOTTED CUMULATIVE RECOVERY AS A FUNCTION OF CUMULATIVE FLOTATION TIME FOR EACH SIZE FRACTION. THE GREATEST RECOVERY WAS ATTAINED FOR THE 74 TO 104 MICRON SIZE FRACTION, AND THE RECOVERY DECREASED AS THE PARTICLE SIZE INCREASED OR DECREASED FROM THE OPTIMUM SIZE. THE VALIDITY OF THE KIDD AND WALL TESTS ON THE ELUTRICATED FRACTIONS ARE QUESTIONABLE. THE ELUTRIATED FRACTIONS WERE SUBJECTED TO GUM ARABIC, WHICH WAS USED FOR A DISPERSING AGENT, AND THEY FAILED TO CLEAN THE SPHALERITE

PARTICLES BEFORE THEY WERE FLOATED. THE RATE OF FLOTATION OF THESE SIZE FRACTIONS WOULD BE EXPECTED TO BE RETARDED SINCE THEY WERE COATED WITH A DEPRESSANT.

RESULTS FROM FLOTATION TESTS USING A BATCH CELL AND COLLECTING GALENA CONCENTRATE MADE BY GAUDIN, GROH, AND HENDERSON⁽¹⁶⁾ INDICATE THAT THE LARGEST SIZE, 20 MESH,

(16) GAUDIN, A. M., GROH, J. O., AND HENDERSON, H. B., EFFECT OF PARTICLE SIZE ON FLOTATION: AM. INST. MIN. MET. ENG. T. P. 414, 1930.

FLOATED FASTEST AND THE FLOTATION RATE DECREASED AS THE PARTICLE SIZE DECREASED. THESE RESULTS ARE CONTRARY TO THE RESULTS OBTAINED BY MORRIS AND KIDD AND WALL AS PREVIOUSLY DISCUSSED.

GAUDIN, SCHUHMAN, AND SCHLECHTEN⁽¹⁷⁾ FOUND THAT THE

(17) GAUDIN, A. M., SCHUHMAN, R., JR., AND SCHLECHTEN, A. W., THE EFFECT OF SIZE ON THE BEHAVIOR OF GALENA PARTICLES: JOUR. OF PHYSICAL AND COLLOID CHEM., VOL. 46, PP. 902-910, 1942.

SPECIFIC FLOTATION RATE OF GALENA INCREASED AS THE PARTICLE SIZE INCREASED. THEY USED PARTICLE SIZES OF LESS THAN 40 MICRONS IN DIAMETER. THE SPECIFIC FLOTATION RATE OF ANY SIZE FRACTION IS DEFINED AS THE GRAMS OF THAT SIZE FRACTION FLOATED PER MINUTE DIVIDED BY THE GRAMS OF THAT SIZE FRACTION IN THE CELL. THEY CONDUCTED THEIR EXPERIMENTS USING A STEADY STATE FLOTATION CELL.

A GRAPH OF THE FLOTATION RATE CONSTANT VERSUS THE MEAN DIAMETER OF THE PARTICLES INDICATES THAT THE FLOTATION

RATE INCREASES AS THE PARTICLE SIZE INCREASES UNTIL A MAXIMUM FLOTATION RATE IS REACHED BETWEEN 60 AND 89 MICRONS. THIS RELATIONSHIP WAS SEEN TO EXIST FOR IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE AS SHOWN IN FIGURES 21, 22, AND 23. AT SLOWER SPEEDS OF 863 AND 1294 REVOLUTIONS PER MINUTE THE FLOTATION RATE REMAINED FAIRLY CONSTANT OR DECREASED AS THE PARTICLE SIZE INCREASED. THIS IS ALSO SHOWN IN FIGURES 21, 22, AND 23. AS THE PARTICLE SIZE INCREASED BEYOND THE 60 TO 89 MICRON RANGE THE FLOTATION RATE DECREASED. THIS CONDITION EXISTED FOR EACH OF THE FOUR SPEEDS.

FIRST LET US CONSIDER WHAT HAPPENS WHEN THE IMPELLER SPEED VARIES AND THE AIR VOLUME REMAINS CONSTANT. THERE ARE TWO FACTORS INVOLVED IN REMOVING THE VALUABLE MINERALS FROM THE FLOTATION CELL IN THE FORM OF FROTH. FIRST THE SOLID AND BUBBLE MUST UNITE, AND SECOND, THE BUBBLE SOLID AGGREGATE MUST BE CAPABLE OF REACHING THE SURFACE WITHOUT BEING DISRUPTED.

BASED ON THE COLLISION THEORY OF BUBBLE PARTICLE UNION, SUTHERLAND'S ⁽¹⁸⁾ ANALYSIS PREDICTS THAT THE

(18) SUTHERLAND, K. L., KINETICS OF THE FLOTATION PROCESS: JOUR. OF PHYSICAL AND COLLOID CHEM., VOL. 52, PP. 394-425, 1948.

FLOTATION RATE CONSTANT WOULD INCREASE AS THE PARTICLE SIZE INCREASES UNTIL THE MAXIMUM PARTICLE SIZE FLOATABLE IS REACHED. THE FLOTATION RATE BEING DIRECTLY PROPORTIONAL TO THE DIAMETER OF THE PARTICLE.

MORRIS⁽¹⁹⁾ MEASURED THE FORCES ACTING BETWEEN A

(19) MORRIS, T. M. MEASUREMENT OF EQUILIBRIUM FORCES BETWEEN AN AIR BUBBLE AND AN ATTACHED SOLID IN WATER: AM. INST. MIN. MET. ENG. TRANS., VOL. 187, PP. 91-96, 1950.

BUBBLE AND PARTICLE UNDER STATIC CONDITIONS. HE FOUND THE PROBABILITY OF THE BUBBLE PARTICLE SYSTEM BEING CAPABLE OF WITHSTANDING THE DISRUPTIVE FORCES PRESENT IN THE FLOTATION CELL WAS GREATER FOR ANY GIVEN BUBBLE THE SMALLER THE SIZE OF THE ATTACHED PARTICLE. THEREFORE, THE GREATER WOULD BE THE PROBABILITY OF THE PARTICLE BUBBLE AGGREGATE REACHING THE SURFACE AND BEING REMOVED.

NOW CONSIDER THE ASCENDING PORTION OF THE FLOTATION RATE VERSUS PARTICLE SIZE CURVE FOR IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE. AT THE FASTER SPEED MORE WORK IS PUT INTO THE SYSTEM AND IT WOULD BE EXPECTED THAT MORE BUBBLES WOULD BE PRODUCED, SINCE WORK IS REQUIRED TO OVERCOME THE SURFACE ENERGY EXISTING BETWEEN THE AIR WATER INTERFACE. SINCE THE AIR VOLUME IS CONSTANT FOR BOTH SPEEDS AND THERE WOULD BE A GREATER NUMBER OF BUBBLES PRESENT AT THE HIGHER SPEED, THE SIZE OF THE BUBBLES PRODUCED AT THE HIGHER SPEED WOULD BE EXPECTED TO BE SMALLER IN SIZE. ACCORDING TO SUTHERLAND'S ANALYSIS THE ASCENDING CURVE WOULD BE EXPECTED, BUT WHY SHOULD THE SMALLER SIZES FLOAT SLOWER FOR THE HIGHER SPEED AND FASTER AT THE SLOWER SPEED. THE VELOCITY OF THE PARTICLES AND BUBBLES INCREASE WITH AN INCREASE IN IMPELLER SPEED AND

IT BECOMES MORE DIFFICULT FOR THE SMALLER PARTICLES TO UNITE WITH A BUBBLE. THE INERTIA OF THE SMALL PARTICLES IS INSUFFICIENT IN MANY INSTANCES TO ALLOW THEM TO PENETRATE THE FILM FORMED BY THE LAMINAR FLOW OF FLUID AROUND THE BUBBLE AND FORM A BUBBLE PARTICLE AGGREGATE. THE SMALL PARTICLES THAT ARE CAPABLE OF UNITING WITH A BUBBLE HAVE A GREATER CHANCE OF REACHING THE SURFACE THAN THE LARGER BUBBLE.

AS THE PARTICLE SIZE INCREASES TO THE OPTIMUM SIZE, THE PROBABILITY OF A BUBBLE PARTICLE AGGREGATE REACHING THE SURFACE DECREASES. HOWEVER, THE PROBABILITY OF A BUBBLE AND PARTICLE UNITING INCREASES SINCE THE INERTIA OF THE PARTICLE INCREASES WITH THE PARTICLE SIZE. THE FLOTATION RATE WOULD BE EXPECTED TO INCREASE WITH PARTICLE SIZE AS IS INDICATED BY THE EXPERIMENTAL RESULTS.

AT SLOWER IMPELLER SPEEDS OF 863 AND 1294 REVOLUTIONS PER MINUTE THE FLOTATION RATE REMAINS FAIRLY CONSTANT OR DECREASES AS THE PARTICLE SIZE INCREASES. AT THESE SLOWER IMPELLER SPEEDS THE DISRUPTIVE FORCES WITHIN THE CELL ARE LESS THAN AT HIGHER SPEEDS, AND THE FILM FORMED BY THE LAMINAR FLOW OF FLUID AROUND THE BUBBLE DOES NOT OFFER AS MUCH RESISTANCE TO PENETRATION BY A MOVING PARTICLE. ALTHOUGH THE INERTIA OF THE PARTICLES HAS DECREASED, IT IS SUFFICIENT TO PERMIT THE PARTICLES AND BUBBLES TO UNITE. THE PROBABILITY OF THE LARGER PARTICLES, BECAUSE OF THEIR INERTIA, OF UNITING WITH BUBBLES IS

GREATER THAN THE SMALL PARTICLES, BUT THE PROBABILITY OF THE SMALL PARTICLES OF REACHING THE SURFACE ATTACHED TO A BUBBLE IS GREATER THAN THE LARGER PARTICLES. THEREFORE, AT THE SLOWER IMPELLER SPEEDS THE FLOTATION RATE MAY BE EXPECTED TO REMAIN FAIRLY CONSTANT OR DECREASE AS THE PARTICLE SIZE INCREASES AS WAS INDICATED BY THE RESULTS.

AS THE PARTICLE SIZE INCREASED FROM THE OPTIMUM SIZE OF 60 TO 89 MICRONS, THE FLOTATION RATE WAS FOUND TO DECREASE. THE DECREASE IN RATE WAS FOUND TO BE MORE RAPID AT HIGHER IMPELLER SPEEDS. THE PROBABILITY OF BUBBLE PARTICLE ATTACHMENT INCREASES WITH AN INCREASE IN PARTICLE SIZE AS BEFORE, BUT THE PROBABILITY OF THE BUBBLE PARTICLE AGGREGATE REACHING THE SURFACE DECREASES. THE LATER ACTION IS PREDOMINANT FOR THE LARGER PARTICLE SIZES. THE FLOTATION RATE OF THE LARGER PARTICLES WAS FOUND TO DECREASE MORE RAPIDLY AT HIGHER IMPELLER SPEEDS WHICH IS IN ACCORDANCE WITH THE REASONING SINCE THE DISRUPTIVE FORCES INCREASE WITH AN INCREASE IN IMPELLER SPEED. ALTHOUGH THE INERTIA OF THE PARTICLES INCREASE WITH SPEED, THE DISRUPTIVE FORCES OVERCOME THIS APPARENT ADVANTAGE SINCE IT IS MORE DIFFICULT FOR A LARGE PARTICLE TO REMAIN ATTACHED TO A BUBBLE THAN A SMALL PARTICLE.

THE VALUES OF K APPEAR TO BE LOW AS SHOWN IN FIGURE 22 FOR THE 60 AND 89 MICRON SIZE FRACTIONS AT AN IMPELLER SPEED OF 1725 REVOLUTIONS PER MINUTE. THIS MAY BE

ACCOUNTED FOR BY REFERRING TO FIGURE 2. THE THREE-HALVES ORDER RATE EQUATION DOES NOT FIT THE DATA VERY WELL FOR THESE TWO SIZE FRACTIONS, AND THERE IS A DRIFT IN THE K VALUE AS THE FLOTATION TIME INCREASES. THESE TWO K VALUES SHOULD BE GREATER. SIMILARLY THE K VALUE FOR THE 60 MICRON SIZE FRACTION AT AN IMPELLER SPEED OF 1294 REVOLUTIONS PER MINUTE SHOULD BE GREATER AS SEEN IN FIGURE 23. THIS K VALUE DRIFTS WITH AN INCREASE IN TIME AS MAY BE OBSERVED IN FIGURE 14.

FROM FIGURES 21, 22, AND 23 IT CAN BE SEEN THAT WITH AN AIR VOLUME OF 1.0 LITER PER MINUTE THE FLOTATION RATE DECREASES FROM THE MAXIMUM RATE AS THE PARTICLE SIZE BECOMES LARGER OR SMALLER FOR ALL OF THE IMPELLER SPEEDS STUDIED. THIS RELATIONSHIP REMAINS THE SAME AT IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE AS THE AIR VOLUME INCREASED FROM 1.0 TO 3.5 LITERS PER MINUTE. THIS IS SHOWN IN FIGURES 22 AND 23 AND HOLDS FOR AIR VOLUMES OF 2.5 AND 3.5 LITERS PER MINUTE. AT THE SLOWER IMPELLER SPEEDS OF 863 AND 1294 REVOLUTIONS PER MINUTE THE FLOTATION RATE INCREASES WITH A DECREASE IN PARTICLE SIZE AS THE AIR VOLUME INCREASES WHICH IS SHOWN IN FIGURES 22 AND 23. THIS TREND ALSO EXISTS AT AIR VOLUMES OF 2.5 AND 3.5 LITERS PER MINUTE. IN ORDER TO ATTAIN THE OPTIMUM FLOTATION CONDITIONS IT IS NECESSARY TO CONSIDER THE EFFECT OF A VARIATION IN AIR VOLUME ON THE IMPELLER SPEED WHICH HAS BEEN ILLUSTRATED.

THE VARIATION OF THE FLOTATION RATE CAUSED BY A CHANGE IN THE AIR VOLUME WHEN THE IMPELLER SPEED IS CONSTANT WILL NOW BE CONSIDERED. AT THE SLOWEST IMPELLER SPEED OF 863 REVOLUTIONS PER MINUTE A CHANGE IN AIR VOLUME DID NOT NOTICEABLY CHANGE THE FLOTATION RATE WITH RESPECT TO PARTICLE SIZE UNTIL THE AIR VOLUME WAS 3.5 LITERS PER MINUTE. THIS MAY BE OBSERVED FROM FIGURE 24. THE REASON FOR THE SUDDEN CHANGE IN FLOTATION RATE AT THIS AIR VOLUME IS DIFFICULT TO DETERMINE. IN ORDER TO ANALYZE THIS SITUATION IT WOULD BE NECESSARY TO OBTAIN AT LEAST ONE MORE SET OF DATA TO DETERMINE IF COMPARABLE RESULTS WOULD BE OBTAINED.

WHEN THE IMPELLER SPEED WAS INCREASED TO 1294 REVOLUTIONS PER MINUTE, THE CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE WAS SMALL AS THE PARTICLE SIZE DECREASED UNTIL REACHING 60 MICRONS. AS THE PARTICLE SIZE DECREASED FURTHER, THE FLOTATION RATE INCREASED AS THE AIR VOLUME INCREASED FOR EACH SIZE FRACTION. AS THE PARTICLE SIZE DECREASED THE FLOTATION RATE FOR EACH SIZE FRACTION INCREASED MORE RAPIDLY AS THE AIR VOLUME INCREASED.

AT THE SLOWER OF THE TWO IMPELLER SPEEDS, 863 AND 1294 REVOLUTIONS PER MINUTE, THE WORK PUT INTO THE SYSTEM APPEARS TO BE INSUFFICIENT TO UTILIZE THE ADDITIONAL VOLUME OF AIR ADDED TO THE FLOTATION CELL. CONSEQUENTLY THE ADVANTAGE TO BE GAINED FROM HAVING MORE AIR BUBBLES IN THE CELL IS ELIMINATED SINCE TOO MUCH WORK IS REQUIRED

TO CREATE THE ADDITIONAL BUBBLES. WHEN THE IMPELLER SPEED HAS BEEN INCREASED TO 1294 REVOLUTIONS PER MINUTE, MORE WORK HAS BEEN PUT INTO THE SYSTEM AND MORE BUBBLES RESULT IN THE CELL AS THE AIR VOLUME IS INCREASED. THE FLOTATION RATES OF THE SMALLEST SIZE PARTICLES ARE THE FIRST TO INDICATE AN INCREASE WITH AN INCREASE IN THE AIR VOLUME. THIS MAY BE EXPECTED SINCE THE SMALLEST PARTICLES HAVE THE GREATEST PROBABILITY OF REACHING THE SURFACE AS A BUBBLE PARTICLE AGGREGATE. ALSO THE INERTIA OF THE SMALLEST PARTICLES IS OF SUFFICIENT MAGNITUDE TO PENETRATE THE FILM FORMED BY THE LAMINAR FLOW OF FLUID AROUND THE BUBBLE AND UNITE WITH THE BUBBLE AT THIS IMPELLER SPEED.

WITH AN INCREASE IN IMPELLER SPEED TO 1725 AND 2048 REVOLUTIONS PER MINUTE THE NUMBER OF BUBBLES FORMED INCREASES AS THE AIR VOLUME INCREASES. THIS IS POSSIBLE SINCE THERE HAS BEEN AN INCREASE IN THE AMOUNT OF WORK PUT INTO THE SYSTEM. WITH MORE BUBBLES PRESENT THE FLOTATION RATES OF THE VARIOUS SIZED PARTICLES INCREASED FOR A GIVEN SPEED. HAVING MORE BUBBLES IN THE CELL, THERE EXISTED A GREATER PROBABILITY OF BUBBLE PARTICLE UNION WHICH PRODUCED AN INCREASE IN FLOTATION RATE WITH AN INCREASE IN AIR VOLUME. FIGURE 26 INDICATES THE CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE WITH A CHANGE IN AIR VOLUME AT AN IMPELLER SPEED OF 2048 REVOLUTIONS PER MINUTE. IN THIS FIGURE THE RESULTS FROM THE TEST MADE HAVING AN AIR VOLUME OF 2.5 LITERS PER

MINUTE ARE NOT IN ACCORDANCE WITH THE REASONING. BY OBSERVING THE RESULTS SHOWN IN FIGURE 8, IT CAN BE SEEN THAT THE DATA OBTAINED IN THIS TEST DOES NOT FIT THE THREE-HALVES ORDER RATE EQUATION VERY WELL. THIS IS A POSSIBLE EXPLANATION OF WHY THESE RESULTS ARE NOT IN AGREEMENT WITH THE GENERAL TREND. IN ANY CASE, THE RESULTS OF THIS TEST ARE QUESTIONABLE. AT IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE THE FLOTATION RATE WAS A MAXIMUM FOR THE SIZE RANGE OF 74 TO 104 MICRONS AS THE AIR VOLUME WAS INCREASED FROM 1.0 TO 3.5 LITERS PER MINUTE. THE FLOTATION RATE DECREASED AS THE PARTICLE SIZE INCREASED OR DECREASED FROM THE OPTIMUM SIZE RANGE.

AT PRESENT THE GENERAL PRACTICE IS TO OPERATE ALL OF THE FLOTATION CELLS IN A BANK OF CELLS AT THE SAME IMPELLER SPEED AND AIR VOLUME. THE RESULTS OF THE INVESTIGATION INDICATE, THAT WITH A KNOWLEDGE OF THE EFFECT OF IMPELLER SPEED AND AIR VOLUME ON THE FLOTATION RATE OF EACH SIZE FRACTION OF THE ORE, THE MILL OPERATOR WOULD HAVE A VALUABLE TOOL FOR CONTROLLING THE RECOVERY PER UNIT TIME. THE FOLLOWING EXAMPLE SHOWS HOW THIS COULD BE ACCOMPLISHED FOR REFLOATING THE PYRITE-PYRRHOTITE CONCENTRATES USED IN THE EXPERIMENTAL WORK. FIGURE 23 SHOWS THAT THE FLOTATION RATE OF EACH SIZE FRACTION INCREASES AS THE PARTICLE SIZE DECREASES WHEN THE IMPELLER SPEED WAS 1294 REVOLUTIONS PER MINUTE. IN FIGURE 22 IT

CAN BE SEEN THAT THE FLOTATION RATE IS A MAXIMUM FOR THE SIZE FRACTION OF 89 MICRONS AND DECREASES AS THE PARTICLE SIZE INCREASES OR DECREASES FOR AN IMPELLER SPEED OF 2048 REVOLUTIONS PER MINUTE. BY KNOWING THE SIZE DISTRIBUTION OF THE FLOTATION FEED AND THE NUMBER OF FLOTATION CELLS REQUIRED FOR THE OPERATION, THE IMPELLER SPEED AND AIR VOLUME COMBINATIONS FOR EACH CELL COULD BE DETERMINED IN ORDER TO INCREASE THE RECOVERY PER UNIT TIME. THAT IS, IF THE SIZE DISTRIBUTION OF THE FEED WAS 50 PER CENT MINUS 89 MICRONS AND 50 PER CENT 89 TO 178 MICRONS AND FOUR CELLS WERE REQUIRED, AN INCREASE IN THE RECOVERY PER UNIT TIME COULD BE ATTAINED BY OPERATING TWO CELLS AT AN IMPELLER SPEED OF 1294 REVOLUTIONS PER MINUTE AND AN AIR VOLUME OF 3.0 LITERS PER MINUTE. THE OTHER TWO CELLS WOULD BE OPERATED AT AN IMPELLER SPEED OF 2048 REVOLUTIONS PER MINUTE AND AN AIR VOLUME OF 2.0 LITERS PER MINUTE. AN ARRANGEMENT OF THIS NATURE WOULD ALLOW THE MINUS 89 MICRONS MATERIAL TO BE FLOATED FASTER IN THE CELLS OPERATED AT A SLOWER IMPELLER SPEED, AND THE 89 TO 178 MICRON MATERIAL WOULD FLOAT FASTER IN THE CELLS OPERATING AT A FASTER IMPELLER SPEED. OTHER FACTORS SUCH AS POWER AND MAINTENANCE WOULD HAVE TO BE CONSIDERED IN DETERMINING THE MOST ECONOMICAL COMBINATIONS OF THE IMPELLER SPEED AND AIR VOLUME FOR EACH CELL NECESSARY TO INCREASE THE RECOVERY PER UNIT TIME. HOWEVER, THE RESULTS INDICATE THAT VARIATIONS CAN BE MADE IN THE AIR VOLUME AND IMPELLER SPEED TO INCREASE THE RECOVERY PER UNIT TIME.

SUMMARY OF CONCLUSIONS

1. AT ALL OF THE IMPELLER SPEEDS STUDIED AND AN AIR VOLUME OF 1.0 LITER PER MINUTE THE FLOTATION RATE WAS FOUND TO DECREASE FROM THE MAXIMUM RATE AS THE PARTICLE SIZE DECREASED OR INCREASED FROM THE SIZE HAVING THE MAXIMUM RATE.
2. USING IMPELLER SPEEDS OF 863 AND 1294 REVOLUTIONS PER MINUTE AND AIR VOLUMES OF 2.0, 2.5, 3.0, AND 3.5 LITERS PER MINUTE THE FLOTATION RATE WAS FOUND TO INCREASE AS THE PARTICLE SIZE DECREASED.
3. USING IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE AND AIR VOLUMES OF 2.0, 2.5, 3.0, AND 3.5 LITERS PER MINUTE THE FLOTATION RATE WAS FOUND TO DECREASE FROM THE MAXIMUM RATE AS THE PARTICLE SIZE DECREASED OR INCREASED FROM THE SIZE HAVING THE MAXIMUM FLOTATION RATE.
4. USING AN IMPELLER SPEED OF 863 REVOLUTIONS PER MINUTE A CHANGE IN AIR VOLUME DID NOT NOTICEABLY CHANGE THE FLOTATION RATE WITH RESPECT TO PARTICLE SIZE.
5. USING AN IMPELLER SPEED OF 1294 REVOLUTIONS PER MINUTE A CHANGE IN AIR VOLUME PRODUCED A SMALL CHANGE IN THE FLOTATION RATE FOR PARTICLES OF 60 MICRONS OR GREATER. FOR PARTICLES LESS THAN 60 MICRONS THE FLOTATION RATE INCREASED WITH AN INCREASE IN AIR VOLUME.

6. USING IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE THE FLOTATION RATE OF THE VARIOUS SIZE FRACTIONS INCREASED WITH AN INCREASE IN AIR VOLUME.
7. WITH A KNOWLEDGE OF THE EFFECT OF IMPELLER SPEED AND AIR VOLUME ON THE FLOTATION RATE CONSTANT WITH RESPECT TO PARTICLE SIZE, THE IMPELLER SPEED AND AIR VOLUME OF EACH FLOTATION CELL IN A BANK OF CELLS COULD BE CONTROLLED IN ORDER TO INCREASE THE RECOVERY PER UNIT TIME FOR A GIVEN ORE.

TABLE 33

CALCULATED DATA FOR TEST 1-1

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	19.78	80.22	0.1116	22.75	77.25	0.1138	19.84	80.16	0.1117
40	12.62	67.60	0.1216	12.47	64.78	0.1242	11.44	68.72	0.1206
60	8.60	59.00	0.1302	8.14	56.64	0.1329	12.58	56.14	0.1335
90	10.66	48.34	0.1439	12.10	44.54	0.1498	15.67	40.47	0.1572
150	12.90	35.44	0.1680	15.90	28.64	0.1868	14.48	25.99	0.1962
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.54	99.46	0.1003	26.05	73.95	0.1163	24.19	75.81	0.1149
40	0.36	99.10	0.1005	16.71	57.24	0.1322	10.56	65.25	0.1238
60	0.25	98.85	0.1006	10.41	46.83	0.1461	10.33	54.92	0.1368
90	0.54	98.31	0.1009	11.79	35.04	0.1689	11.50	43.42	0.1518
150	1.87	96.44	0.1018	11.89	23.15	0.2123	12.04	31.38	0.1818
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	4.02	95.89	0.1021	24.61	75.39	0.1152	26.41	73.59	0.1166
40	2.72	93.26	0.1036	14.88	60.51	0.1286	11.92	61.67	0.1273
60	1.84	91.42	0.1046	10.28	50.23	0.1411	7.26	54.51	0.1310
90	4.35	87.07	0.1072	12.03	38.20	0.1618	6.40	48.01	0.1443
150	11.04	76.03	0.1147	10.85	27.35	0.1949	7.20	40.81	0.1565
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	14.15	85.85	0.1079	21.69	78.31	0.1130	8.02	91.98	0.1043
40	8.87	76.98	0.1140	14.28	64.03	0.1250	9.48	82.50	0.1101
60	6.47	70.51	0.1191	8.24	55.79	0.1339	8.65	73.85	0.1164
90	12.58	57.93	0.1331	14.47	41.32	0.1556	11.18	62.67	0.1263
150	19.03	38.90	0.1603	13.47	27.85	0.1895	9.92	52.75	0.1377

APPENDIX

TABLE 34

CALCULATED DATA FOR TEST 1-2

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	23.46	76.54	0.1143	23.03	76.97	0.1140	23.39	76.61	0.1142
40	13.05	63.49	0.1255	11.96	65.01	0.1240	17.25	59.36	0.1315
60	7.51	55.98	0.1337	7.25	57.76	0.1333	10.74	48.62	0.1434
90	8.58	47.40	0.1452	8.69	49.07	0.1428	11.52	37.10	0.1642
150	10.67	36.73	0.1650	10.50	38.57	0.1610	12.67	24.43	0.2023
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.82	99.18	0.1004	26.64	73.36	0.1168	21.36	78.64	0.1128
40	0.76	98.42	0.1008	14.12	59.24	0.1299	16.29	62.35	0.1266
60	0.50	97.92	0.1011	6.89	52.35	0.1382	10.84	51.51	0.1393
90	1.12	96.80	0.1016	5.96	46.39	0.1468	11.92	39.59	0.1589
150	4.67	92.13	0.1042	8.22	38.17	0.1618	13.88	25.71	0.1972
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	9.98	90.02	0.1054	32.87	67.13	0.1221	9.69	90.31	0.1052
40	3.25	86.76	0.1073	16.43	50.70	0.1404	17.93	72.38	0.1166
60	1.88	84.89	0.1085	8.19	42.51	0.1534	3.89	68.49	0.1208
90	4.04	80.85	0.1112	9.53	32.98	0.1741	6.33	62.16	0.1268
150	9.29	71.56	0.1182	10.31	22.67	0.2100	15.80	46.36	0.1469
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>-8 MICRONS</u>		
20	28.78	71.22	0.1185	28.50	71.50	0.1183	20.35	79.65	0.1120
40	9.62	61.60	0.1274	17.53	53.97	0.1361	14.55	65.10	0.1239
60	5.45	56.15	0.1335	10.24	43.73	0.1535	12.06	53.04	0.1373
90	8.66	47.49	0.1451	10.55	33.18	0.1736	14.52	38.52	0.1611
150	11.66	35.83	0.1671	11.49	21.69	0.2147	10.54	27.98	0.1890

TABLE 35

CALCULATED DATA FOR TEST 1-3

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	25.04	74.96	0.1155	27.43	72.57	0.1174	25.10	74.90	0.1156
40	16.02	58.94	0.1303	15.76	56.81	0.1327	19.47	55.43	0.1343
60	10.14	48.80	0.1431	11.07	45.74	0.1479	12.11	43.32	0.1519
90	8.45	40.35	0.1574	9.60	36.14	0.1663	10.45	32.87	0.1744
150	8.19	32.16	0.1763	9.15	26.99	0.1925	9.92	22.95	0.2087
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.53	99.47	0.1003	34.05	65.95	0.1231	23.75	76.25	0.1145
40	0.44	99.03	0.1005	13.89	52.06	0.1386	19.25	57.00	0.1325
60	0.70	98.33	0.1008	9.82	42.24	0.1539	12.74	44.26	0.1503
90	1.06	97.27	0.1014	6.79	35.45	0.1680	11.72	32.54	0.1753
150	1.58	95.69	0.1022	4.07	31.38	0.1785	11.89	20.65	0.2201
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	5.29	94.71	0.1028	36.40	63.60	0.1254	20.37	79.63	0.1121
40	4.70	90.01	0.1054	25.14	38.46	0.1662	18.43	61.20	0.1278
60	4.78	85.23	0.1083	10.48	27.98	0.1890	13.17	48.03	0.1443
90	5.49	79.74	0.1120	7.17	20.81	0.2192	9.31	38.72	0.1606
150	6.25	73.49	0.1167	8.51	12.30	0.2851	12.42	26.30	0.1950
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>-8 MICRONS</u>		
20	18.15	81.85	0.1105	30.17	69.83	0.1197	23.24	76.76	0.1141
40	13.63	68.22	0.1211	19.00	50.83	0.1403	23.52	53.24	0.1370
60	11.50	56.72	0.1328	11.62	39.21	0.1597	14.04	39.20	0.1597
90	9.97	46.75	0.1462	9.68	29.53	0.1840	12.15	27.05	0.1923
150	9.59	37.16	0.1640	8.92	20.61	0.2203	10.16	16.89	0.2433

TABLE 36

CALCULATED DATA FOR TEST 1-4

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	24.45	75.55	0.1151	27.48	72.52	0.1175	23.93	76.07	0.1147
40	13.09	62.46	0.1265	13.09	59.43	0.1314	17.43	58.64	0.1306
60	9.60	52.86	0.1375	9.88	49.55	0.1421	9.28	49.36	0.1423
90	9.71	43.15	0.1522	10.48	39.07	0.1600	15.03	34.33	0.1707
150	11.11	32.04	0.1767	13.15	25.92	0.1964	13.92	20.41	0.2263
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.73	99.27	0.1004	32.56	67.44	0.1218	22.17	77.83	0.1134
40	0.41	98.86	0.1006	15.31	52.13	0.1385	16.98	60.85	0.1282
60	0.33	98.53	0.1007	11.48	40.65	0.1568	12.49	48.36	0.1438
90	0.51	98.02	0.1010	10.54	30.11	0.1822	12.42	35.94	0.1668
150	1.82	96.20	0.1030	11.30	18.81	0.2306	11.55	24.39	0.2025
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	7.26	92.74	0.1038	29.22	70.78	0.1203	21.15	78.85	0.1126
40	3.69	89.05	0.1060	17.37	53.41	0.1368	23.58	55.27	0.1345
60	2.84	86.21	0.1077	11.31	42.10	0.1541	9.11	46.16	0.1472
90	4.36	81.85	0.1105	11.89	30.21	0.1820	9.62	36.54	0.1654
150	9.84	72.01	0.1178	9.54	20.67	0.2200	13.92	22.62	0.2102
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>-8 MICRONS</u>		
20	20.06	79.94	0.1118	25.42	74.58	0.1158	24.25	75.75	0.1149
40	10.14	69.80	0.1197	16.80	57.78	0.1316	17.71	58.04	0.1313
60	7.61	62.19	0.1272	11.97	45.81	0.1478	10.04	48.00	0.1443
90	9.82	52.37	0.1382	11.90	33.91	0.1747	12.58	35.42	0.1680
150	14.81	37.56	0.1632	11.01	22.90	0.2090	13.39	22.03	0.2130

TABLE 37

CALCULATED DATA FOR TEST 1-5

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	28.21	71.79	0.1180	33.08	66.92	0.1222	29.92	70.08	0.1195
40	15.44	56.35	0.1350	16.32	50.60	0.1406	19.62	50.46	0.1408
60	8.78	47.57	0.1450	9.81	40.79	0.1566	11.85	38.61	0.1609
90	8.83	38.74	0.1607	10.28	30.51	0.1810	11.69	26.92	0.1928
150	9.27	29.47	0.1877	11.08	19.43	0.2321	7.15	19.77	0.2249
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.59	99.41	0.1003	36.90	63.10	0.1259	29.49	70.51	0.1191
40	0.51	98.90	0.1006	10.93	52.17	0.1384	21.26	49.25	0.1425
60	0.37	98.53	0.1007	5.71	46.46	0.1489	13.54	35.71	0.1673
90	0.63	97.90	0.1011	4.97	41.49	0.1553	14.17	21.54	0.2155
150	1.76	96.14	0.1020	13.81	27.68	0.1901	2.12	19.42	0.2269
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	5.89	94.11	0.1031	33.53	66.47	0.1227	29.96	70.04	0.1195
40	5.07	89.04	0.1060	23.02	43.45	0.1517	13.32	56.72	0.1328
60	3.40	85.64	0.1081	11.12	32.33	0.1759	19.92	36.80	0.1649
90	4.96	80.68	0.1113	10.20	22.13	0.2126	19.61	17.19	0.2412
150	9.07	71.61	0.1182	8.12	14.01	0.2672	3.93	13.26	0.2746
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	21.70	78.30	0.1130	36.10	63.90	0.1251	37.96	62.04	0.1270
40	13.91	64.39	0.1246	20.25	43.65	0.1537	-----	-----	-----
60	8.79	55.60	0.1341	11.51	32.14	0.1764	43.50	18.54	0.2322
90	10.56	45.04	0.1490	10.55	21.59	0.2152	10.72	9.82	0.3577
150	12.51	32.53	0.1753	6.82	14.77	0.2602	3.62	4.20	0.4880

TABLE 38

CALCULATED DATA FOR TEST 2-1

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	17.74	82.26	0.1103	17.41	82.59	0.1100	17.15	82.85	0.1099
40	12.95	69.31	0.1201	15.88	66.71	0.1224	14.97	67.88	0.1214
60	8.73	60.58	0.1285	11.54	55.17	0.1346	8.39	59.49	0.1314
90	9.65	50.93	0.1401	11.92	43.25	0.1521	6.86	52.63	0.1378
150	10.73	40.20	0.1577	11.00	32.25	0.1761	11.87	40.76	0.1566
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.86	99.14	1.1004	23.78	76.22	0.1145	16.92	83.08	0.1097
40	1.21	97.93	0.1011	15.12	61.10	0.1279	12.96	70.12	0.1194
60	2.08	95.85	0.1021	8.64	52.46	0.1381	3.03	67.09	0.1221
90	5.58	90.27	0.1053	8.72	43.74	0.1535	9.86	57.23	0.1322
150	14.35	75.92	0.1161	8.68	35.06	0.1689	9.99	47.24	0.1455
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	2.81	97.19	0.1014	21.61	78.39	0.1129	23.85	76.15	0.1146
40	4.62	92.57	0.1039	14.64	63.75	0.1253	20.99	55.16	0.1346
60	6.07	86.50	0.1075	9.34	54.41	0.1356	8.91	46.25	0.1470
90	11.55	74.95	0.1155	9.69	44.72	0.1495	7.15	39.10	0.1599
150	17.10	57.85	0.1332	10.45	34.27	0.1708	7.86	31.24	0.1789
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	10.63	89.37	0.1058	19.79	80.21	0.1117	18.63	81.47	0.1108
40	13.76	75.61	0.1150	13.13	67.08	0.1221	17.90	63.57	0.1254
60	12.55	63.06	0.1259	8.58	58.50	0.1307	5.41	58.16	0.1311
90	14.30	48.76	0.1432	8.26	50.24	0.1411	7.62	50.54	0.1407
150	13.22	35.54	0.1677	9.39	40.85	0.1565	6.25	44.29	0.1503

TABLE 39

CALCULATED DATA FOR TEST 2-2

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	22.79	77.21	0.1138	22.88	77.12	0.1139	24.61	75.39	0.1152
40	17.68	59.53	0.1296	22.48	54.64	0.1353	16.39	59.00	0.1302
60	9.76	49.77	0.1417	12.55	42.09	0.1541	8.86	50.14	0.1412
90	10.83	38.94	0.1603	12.02	30.07	0.1823	10.30	39.84	0.1610
150	12.09	26.85	0.1930	11.22	18.85	0.2303	12.74	27.10	0.1921
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.97	99.03	0.1005	29.95	70.05	0.1195	28.69	71.31	0.1184
40	1.99	97.04	0.1015	19.67	50.38	0.1409	19.87	51.44	0.1394
60	3.46	93.58	0.1034	9.73	40.65	0.1568	6.78	44.66	0.1496
90	10.03	83.55	0.1094	9.89	30.76	0.1803	7.16	37.50	0.1633
150	22.30	61.25	0.1278	10.39	20.37	0.2266	9.90	27.60	0.1903
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	4.07	95.93	0.1021	28.68	71.32	0.1184	30.86	69.14	0.1203
40	8.52	87.41	0.1070	19.28	52.04	0.1386	24.61	44.53	0.1499
60	10.16	77.25	0.1138	8.48	43.56	0.1515	4.71	39.82	0.1610
90	16.42	60.83	0.1282	8.87	34.69	0.1698	3.12	36.70	0.1651
150	19.02	41.81	0.1547	9.93	24.76	0.2010	6.33	30.37	0.1848
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	14.74	85.26	0.1083	25.98	74.02	0.1162	12.53	87.47	0.1069
40	21.01	64.25	0.1248	17.64	56.38	0.1350	16.30	71.17	0.1185
60	14.59	49.66	0.1419	8.54	47.84	0.1467	5.70	65.47	0.1236
90	14.32	35.34	0.1682	9.35	38.49	0.1638	8.13	57.34	0.1321
150	12.70	22.64	0.2102	10.45	28.04	0.1889	10.33	47.01	0.1459

TABLE 40

CALCULATED DATA FOR TEST 2-3

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	27.00	73.00	0.1170	28.48	71.82	0.1180	28.46	71.54	0.1182
40	16.91	56.09	0.1335	21.27	50.54	0.1407	17.34	54.20	0.1358
60	12.59	43.50	0.1516	15.71	34.84	0.1694	12.75	41.45	0.1553
90	10.75	32.75	0.1747	10.97	23.87	0.2047	12.47	28.98	0.1858
150	9.59	23.16	0.2122	8.46	15.41	0.2614	8.29	20.69	0.2198
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.67	99.33	0.1003	34.70	65.30	0.1237	33.06	66.94	0.1222
40	1.90	97.43	0.1013	17.80	47.50	0.1451	11.20	55.74	0.1339
60	4.11	93.32	0.1035	12.44	35.06	0.1689	15.54	40.20	0.1577
90	10.51	82.81	0.1099	9.19	25.87	0.1966	10.81	29.39	0.1879
150	20.46	62.35	0.1266	8.08	17.79	0.2428	10.72	18.67	0.2314
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	3.80	96.20	0.1020	34.80	65.20	0.1238	25.86	74.14	0.1161
40	8.52	87.68	0.1068	20.41	44.79	0.1494	15.59	58.55	0.1307
60	12.89	74.79	0.1156	11.05	33.74	0.1721	12.20	46.35	0.1491
90	16.25	58.54	0.1307	9.60	24.14	0.2035	14.45	31.90	0.1771
150	16.92	41.62	0.1550	6.66	17.48	0.2392	15.62	16.28	0.2478
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>-8 MICRONS</u>		
20	16.80	83.20	0.1096	30.36	69.64	0.1198	22.09	77.91	0.1133
40	20.96	62.24	0.1268	20.84	48.80	0.1431	7.15	70.76	0.1203
60	18.38	43.86	0.1533	10.41	38.39	0.1614	14.59	56.17	0.1334
90	13.48	30.38	0.1848	9.34	29.05	0.1855	13.79	42.38	0.1560
150	9.92	20.46	0.2261	7.53	21.52	0.2156	13.09	29.29	0.1883

TABLE 41

CALCULATED DATA FOR TEST 2-4

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	23.44	76.56	0.1143	22.78	77.22	0.1138	26.10	73.90	0.1163
40	19.04	57.52	0.1319	23.40	53.82	0.1363	18.54	55.36	0.1344
60	9.91	47.61	0.1449	12.64	41.18	0.1558	9.30	46.06	0.1473
90	9.56	38.05	0.1621	10.73	30.45	0.1846	8.31	37.75	0.1628
150	10.88	27.17	0.1919	10.42	20.03	0.2235	12.53	25.22	0.1991
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.74	99.26	0.1004	33.64	66.36	0.1228	18.41	81.59	0.1107
40	1.55	97.71	0.1012	21.92	44.44	0.1500	23.26	58.33	0.1309
60	2.75	94.96	0.1026	9.32	35.12	0.1687	9.94	48.39	0.1438
90	6.93	88.03	0.1066	8.80	26.32	0.1949	6.25	42.14	0.1540
150	16.38	71.65	0.1181	8.71	17.61	0.2383	9.84	32.30	0.1760
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	3.08	96.92	0.1016	26.78	73.22	0.1169	19.10	80.90	0.1112
40	6.75	90.17	0.1053	20.61	52.61	0.1379	26.58	54.32	0.1357
60	8.41	81.76	0.1106	10.21	42.40	0.1560	10.74	43.58	0.1515
90	13.13	68.63	0.1207	7.64	34.76	0.1696	5.09	38.49	0.1612
150	17.91	50.72	0.1404	9.16	25.60	0.1976	9.13	29.36	0.1880
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>~8 MICRONS</u>		
20	12.86	87.14	0.1071	27.11	72.89	0.1171	7.71	92.26	0.1041
40	20.53	66.61	0.1225	19.54	53.35	0.1369	22.20	70.06	0.1195
60	14.53	52.08	0.1386	8.96	44.39	0.1501	16.00	54.06	0.1360
90	13.34	38.74	0.1607	9.00	35.39	0.1681	9.04	45.02	0.1490
150	12.44	26.30	0.1950	9.76	25.63	0.1975	10.27	34.75	0.1696

TABLE 42

CALCULATED DATA FOR TEST 2-5

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	31.16	68.84	0.1205	33.70	66.30	0.1228	29.66	70.34	0.1192
40	17.84	51.00	0.1400	21.97	44.33	0.1502	19.17	51.17	0.1398
60	10.50	40.50	0.1571	11.62	32.71	0.1749	12.55	38.62	0.1609
90	8.71	31.79	0.1774	8.81	23.90	0.2045	9.71	28.91	0.1860
150	10.21	21.58	0.2153	8.69	15.21	0.2564	11.93	16.98	0.2427
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	1.18	98.82	0.1006	41.88	58.12	0.1312	34.96	65.04	0.1240
40	1.97	96.85	0.1016	18.67	39.45	0.1592	16.66	48.38	0.1438
60	3.18	93.67	0.1033	8.67	30.78	0.1802	15.74	32.64	0.1750
90	7.46	86.21	0.1077	6.81	23.97	0.2042	7.42	25.22	0.1991
150	18.59	67.62	0.1216	8.27	15.70	0.2524	11.43	13.79	0.2693
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	5.33	94.67	0.1028	36.56	63.44	0.1255	38.01	61.99	0.1270
40	9.11	85.56	0.1081	19.38	44.06	0.1506	12.30	49.69	0.1419
60	10.35	75.21	0.1153	10.51	33.55	0.1727	18.00	31.69	0.1777
90	13.35	61.86	0.1271	8.84	24.71	0.2012	5.42	26.27	0.1951
150	17.47	44.39	0.1501	8.26	16.45	0.2465	9.09	17.18	0.2413
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	20.90	79.10	0.1124	33.95	66.05	0.1230	35.63	64.37	0.1246
40	22.32	56.78	0.1327	19.67	46.38	0.1490	13.95	50.42	0.1408
60	14.44	42.34	0.1537	10.44	35.94	0.1668	15.53	34.89	0.1693
90	10.96	31.38	0.1785	8.66	27.28	0.1915	6.09	28.80	0.1863
150	10.28	21.10	0.2177	9.50	17.78	0.2371	8.40	20.40	0.2214

TABLE 43

CALCULATED DATA FOR TEST 3-1

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	18.39	81.61	0.1107	19.89	80.11	0.1117	18.53	81.47	0.1108
40	15.47	66.14	0.1230	19.14	60.97	0.1281	15.71	65.76	0.1233
60	10.22	55.92	0.1337	13.16	47.81	0.1468	13.32	52.44	0.1381
90	10.29	45.63	0.1480	11.73	36.08	0.1665	11.58	40.86	0.1564
150	12.76	32.87	0.1744	11.58	24.50	0.2020	15.11	25.75	0.1971
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.84	99.16	0.1004	25.94	74.06	0.1162	17.79	82.21	0.1103
40	1.15	98.01	0.1010	17.21	56.85	0.1326	14.31	67.90	0.1214
60	1.64	96.37	0.1019	9.28	47.57	0.1450	12.04	55.86	0.1338
90	3.51	92.86	0.1038	9.30	38.27	0.1617	10.89	44.97	0.1491
150	10.52	82.34	0.1102	11.62	26.65	0.1937	11.38	33.59	0.1725
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	3.91	96.09	0.1020	18.65	81.35	0.1109	21.61	78.39	0.1129
40	5.51	90.58	0.1051	18.23	63.12	0.1259	13.08	65.31	0.1237
60	6.79	83.79	0.1092	12.91	50.21	0.1411	11.76	53.55	0.1366
90	10.63	73.16	0.1169	10.94	39.27	0.1596	10.17	43.38	0.1518
150	17.58	55.58	0.1341	12.03	27.24	0.1916	13.23	30.15	0.1821
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	13.37	86.63	0.1074	18.47	81.53	0.1108	9.89	90.11	0.1053
40	16.49	70.14	0.1194	16.51	65.02	0.1240	8.09	82.02	0.1104
60	13.97	56.17	0.1334	10.90	54.12	0.1359	8.92	73.10	0.1170
90	14.00	42.17	0.1540	10.53	43.59	0.1515	7.73	65.37	0.1237
150	13.66	28.51	0.1873	12.82	30.77	0.1803	13.06	52.31	0.1383

TABLE 4

CALCULATED DATA FOR TEST 3-2

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	20.95	79.05	0.1125	23.53	76.47	0.1144	19.63	80.37	0.1115
40	15.99	63.06	0.1259	19.75	56.72	0.1328	16.87	63.50	0.1255
60	9.03	54.03	0.1360	10.61	46.11	0.1473	12.09	51.41	0.1395
90	8.80	45.23	0.1487	9.45	36.66	0.1651	10.95	40.46	0.1572
150	11.08	34.15	0.1711	10.21	26.45	0.1944	13.69	26.77	0.1933
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	1.11	98.89	0.1006	26.96	73.04	0.1170	18.30	81.80	0.1106
40	1.22	97.67	0.1012	19.26	53.78	0.1364	14.22	67.58	0.1216
60	1.34	96.33	0.1019	9.19	44.59	0.1497	13.73	53.85	0.1363
90	2.33	94.00	0.1031	7.93	36.66	0.1651	11.35	42.50	0.1534
150	6.50	87.50	0.1069	8.91	27.75	0.1898	15.04	27.46	0.1908
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	4.99	95.01	0.1026	25.14	74.86	0.1156	17.91	82.09	0.1104
40	6.52	88.49	0.1063	15.34	59.52	0.1296	20.45	61.64	0.1274
60	5.77	82.72	0.1100	9.16	50.36	0.1409	12.16	49.48	0.1422
90	8.02	74.70	0.1157	9.53	40.83	0.1565	6.25	43.23	0.1521
150	13.99	60.71	0.1283	12.72	28.11	0.1886	16.35	26.88	0.1929
126 MICRONS				27.5 MICRONS			~8 MICRONS		
20	16.29	83.71	0.1093	21.25	78.75	0.1127	18.43	81.57	0.1107
40	17.67	66.04	0.1231	15.98	62.77	0.1262	14.13	67.44	0.1218
60	11.71	54.33	0.1357	9.58	53.19	0.1371	8.95	58.49	0.1308
90	11.29	43.04	0.1524	9.63	43.56	0.1515	8.06	50.43	0.1408
150	12.30	30.74	0.1804	12.32	31.24	0.1787	10.45	39.98	0.1607

TABLE 45

CALCULATED DATA FOR TEST 3-3

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	24.06	75.94	0.1161	28.23	71.77	0.1180	22.49	77.51	0.1136
40	14.03	61.91	0.1271	16.06	55.71	0.1340	16.48	61.03	0.1280
60	9.21	52.70	0.1378	10.61	45.10	0.1489	12.56	48.47	0.1436
90	8.44	44.26	0.1503	9.07	36.03	0.1666	10.33	38.14	0.1619
150	10.71	33.55	0.1727	10.10	25.93	0.1964	15.36	22.78	0.2095
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	1.06	98.94	0.1005	29.98	70.02	0.1195	29.29	70.71	0.1189
40	0.85	98.09	0.1010	16.71	53.31	0.1370	8.00	62.71	0.1263
60	0.89	97.20	0.1014	10.17	43.14	0.1523	13.86	48.85	0.1431
90	1.52	95.68	0.1022	8.21	34.93	0.1692	5.52	43.33	0.1519
150	3.98	91.70	0.1044	9.28	25.65	0.1974	14.84	28.49	0.1873
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	6.02	93.98	0.1032	29.45	70.55	0.1191	33.63	66.37	0.1227
40	4.31	89.67	0.1056	15.43	55.12	0.1347	8.83	57.54	0.1318
60	4.35	85.32	0.1083	9.97	45.15	0.1488	5.14	52.40	0.1381
90	5.98	79.34	0.1135	9.61	35.54	0.1677	4.44	47.96	0.1444
150	11.71	67.63	0.1201	10.98	24.56	0.2018	16.45	31.51	0.1782
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	19.51	80.49	0.1115	24.81	75.19	0.1153	21.61	78.39	0.1129
40	13.26	67.23	0.1220	15.67	59.52	0.1296	15.28	63.11	0.1269
60	10.79	56.44	0.1349	12.23	47.29	0.1454	8.11	55.00	0.1348
90	10.68	45.76	0.1478	9.76	37.53	0.1632	7.17	47.83	0.1446
150	13.09	32.67	0.1749	11.97	25.56	0.1978	14.40	33.43	0.1730

TABLE 46

CALCULATED DATA FOR TEST 3-4

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	24.58	75.42	0.1151	27.25	72.75	0.1172	23.15	76.85	0.1141
40	14.61	60.81	0.1282	16.74	56.01	0.1336	17.42	59.43	0.1297
60	9.57	51.24	0.1397	11.06	44.95	0.1492	10.72	48.71	0.1433
90	9.04	42.20	0.1539	9.98	34.97	0.1691	12.00	36.71	0.1650
150	10.41	31.79	0.1774	10.19	24.78	0.2009	14.34	22.37	0.2114
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.95	99.05	0.1005	30.67	69.33	0.1201	33.05	66.95	0.1222
40	0.83	98.22	0.1009	16.53	52.80	0.1376	16.49	50.46	0.1408
60	0.87	97.35	0.1013	9.06	43.74	0.1512	14.41	37.05	0.1643
90	1.71	95.64	0.1022	8.25	35.49	0.1679	6.16	29.89	0.1829
150	4.54	91.10	0.1048	9.39	26.10	0.1957	12.12	17.77	0.2372
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	5.40	94.60	0.1028	31.92	68.08	0.1212	28.81	71.19	0.1185
40	4.41	90.19	0.1053	17.00	51.08	0.1399	15.52	55.67	0.1340
60	4.52	85.67	0.1080	11.83	39.25	0.1596	17.92	37.75	0.1628
90	6.99	78.68	0.1127	9.77	29.48	0.1841	7.74	30.01	0.1792
150	12.57	66.11	0.1230	9.56	19.92	0.2241	11.56	18.45	0.2329
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	18.09	81.91	0.1105	27.76	72.24	0.1177	28.37	71.63	0.1182
40	13.98	67.93	0.1228	16.75	55.49	0.1342	13.16	58.47	0.1308
60	11.48	56.45	0.1331	11.19	44.30	0.1502	19.81	38.66	0.1608
90	11.95	44.50	0.1499	11.14	33.16	0.1737	6.28	32.38	0.1757
150	12.82	31.68	0.1777	11.46	21.70	0.2147	7.65	24.73	0.2011

TABLE 47

CALCULATED DATA FOR TEST 3-5

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	28.13	71.87	0.1180	31.88	68.12	0.1212	23.40	76.60	0.1143
40	16.61	55.26	0.1345	18.39	49.73	0.1418	21.17	55.43	0.1343
60	8.94	46.32	0.1469	9.99	39.74	0.1586	11.74	43.69	0.1513
90	8.14	38.18	0.1618	8.34	31.40	0.1784	10.56	33.13	0.1737
150	9.22	28.96	0.1858	8.75	22.65	0.2101	11.55	21.58	0.2153
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	1.14	98.86	0.1006	56.26	43.74	0.1512	25.59	74.41	0.1159
40	1.10	97.76	0.1011	11.12	32.62	0.1751	20.56	53.85	0.1363
60	0.97	96.79	0.1016	5.02	27.60	0.1903	11.45	42.40	0.1536
90	1.58	95.21	0.1025	4.88	22.72	0.2098	10.74	31.66	0.1777
150	3.63	91.58	0.1045	4.84	17.88	0.2365	12.12	19.54	0.2262
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	6.46	93.54	0.1034	28.01	71.99	0.1179	14.06	85.94	0.1079
40	5.85	87.69	0.1068	24.60	47.39	0.1453	33.69	52.25	0.1384
60	4.92	82.77	0.1099	10.34	37.05	0.1643	12.50	39.75	0.1586
90	6.47	76.30	0.1145	7.83	29.22	0.1850	15.89	23.86	0.2047
150	11.16	65.14	0.1239	8.52	20.70	0.2198	7.58	16.28	0.2478
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	21.46	78.54	0.1128	23.40	76.60	0.1143	2.98	97.02	0.1015
40	16.32	62.22	0.1268	21.28	55.32	0.1344	34.62	62.40	0.1266
60	10.79	51.43	0.1395	11.41	43.91	0.1509	17.11	45.29	0.1486
90	10.31	41.12	0.1560	9.84	34.07	0.1714	11.37	33.92	0.1717
150	11.22	29.90	0.1829	10.76	23.31	0.2071	16.09	17.83	0.2368

TABLE 48

CALCULATED DATA FOR TEST 4-1

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	10.95	89.05	0.1060	11.95	88.05	0.1066	12.52	87.48	0.1069
40	12.91	76.14	0.1146	14.53	73.52	0.1166	14.23	73.25	0.1168
60	8.54	67.60	0.1216	9.56	63.96	0.1250	9.97	63.28	0.1257
90	8.88	58.72	0.1305	9.94	44.02	0.1507	10.67	52.61	0.1379
150	11.52	47.20	0.1456	12.39	41.63	0.1550	13.49	39.12	0.1599
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.60	99.40	0.1003	12.13	87.87	0.1067	12.41	87.59	0.1068
40	0.75	98.65	0.1007	13.50	74.37	0.1160	14.20	73.39	0.1167
60	0.71	97.94	0.1011	8.66	65.71	0.1225	9.83	63.56	0.1254
90	1.08	96.89	0.1016	7.32	58.39	0.1309	10.29	53.27	0.1370
150	2.84	94.06	0.1031	9.53	48.86	0.1431	13.82	39.45	0.1592
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	2.53	97.47	0.1013	14.98	85.02	0.1084	13.09	86.91	0.1073
40	3.55	93.92	0.1032	17.50	67.52	0.1217	6.94	79.97	0.1118
60	2.99	90.93	0.1049	9.69	57.83	0.1332	7.54	72.43	0.1175
90	4.13	86.80	0.1073	9.97	47.86	0.1446	9.58	62.85	0.1261
120	8.50	78.30	0.1130	11.50	36.36	0.1658	18.47	44.38	0.1513
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>~8 MICRONS</u>		
20	8.23	91.77	0.1044	12.81	87.19	0.1071	11.25	88.75	0.1061
40	11.30	80.47	0.1115	15.19	72.00	0.1179	19.23	69.52	0.1199
60	8.86	71.61	0.1182	9.93	62.07	0.1269	12.72	56.80	0.1327
90	9.94	61.67	0.1273	10.34	51.73	0.1390	13.31	43.49	0.1516
150	13.94	47.73	0.1447	12.60	39.13	0.1599	13.60	29.89	0.1829

TABLE 49

CALCULATED DATA FOR TEST 4-2

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	12.85	87.15	0.1071	13.58	86.42	0.1076	14.36	85.64	0.1081
40	11.27	75.88	0.1148	12.34	74.08	0.1162	12.87	72.77	0.1172
60	7.47	68.41	0.1209	8.31	65.77	0.1233	8.75	64.02	0.1250
90	9.91	58.50	0.1307	11.30	54.47	0.1355	11.65	52.37	0.1382
150	11.42	47.08	0.1458	12.03	42.44	0.1535	13.47	38.90	0.1603
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.77	99.23	0.1004	16.14	83.86	0.1092	14.09	85.91	0.1079
40	0.69	98.54	0.1007	12.50	71.36	0.1184	12.80	73.11	0.1170
60	0.66	97.88	0.1011	7.53	63.83	0.1252	8.90	64.21	0.1248
90	1.24	96.64	0.1017	8.62	55.21	0.1346	11.82	52.39	0.1382
150	2.84	93.80	0.1033	9.78	45.43	0.1484	14.11	38.28	0.1616
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	2.86	97.14	0.1015	17.32	82.68	0.1100	8.43	91.57	0.1045
40	2.95	94.19	0.1030	14.30	68.38	0.1209	14.35	77.22	0.1138
60	2.47	91.72	0.1044	8.31	60.07	0.1290	10.86	66.36	0.1228
90	4.43	87.29	0.1070	11.42	48.65	0.1434	9.44	56.92	0.1325
150	8.06	79.23	0.1123	11.10	37.55	0.1632	17.70	39.22	0.1597
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>-8 MICRONS</u>		
20	9.77	90.23	0.1053	14.88	85.12	0.1084	20.15	79.85	0.1119
40	9.96	80.27	0.1116	13.00	72.12	0.1178	10.32	69.53	0.1199
60	7.63	72.64	0.1173	8.73	63.39	0.1256	7.65	61.88	0.1271
90	11.05	61.59	0.1274	11.23	52.16	0.1385	12.20	49.68	0.1419
150	13.48	48.11	0.1442	12.53	39.63	0.1589	13.20	36.48	0.1656

TABLE 50

CALCULATED DATA FOR TEST 4-3

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	10.94	89.06	0.1060	11.50	88.50	0.1063	12.82	87.18	0.1071
40	13.42	75.64	0.1150	15.10	73.40	0.1167	14.76	72.42	0.1175
60	8.60	67.04	0.1221	9.48	63.92	0.1251	10.17	62.25	0.1267
90	8.03	59.01	0.1302	8.98	54.94	0.1349	9.45	52.80	0.1376
150	12.78	46.23	0.1471	13.52	41.42	0.1554	14.83	37.97	0.1623
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.74	99.26	0.1004	14.02	85.98	0.1078	12.96	87.04	0.1072
40	0.84	98.42	0.1008	16.76	69.22	0.1202	14.34	72.70	0.1173
60	0.74	97.68	0.1012	8.40	60.82	0.1282	10.39	62.31	0.1267
90	1.10	96.58	0.1018	7.42	53.40	0.1368	9.90	52.41	0.1381
150	3.06	93.52	0.1034	10.23	43.17	0.1522	15.30	37.11	0.1641
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	2.15	97.85	0.1011	13.38	86.62	0.1074	15.46	84.54	0.1088
40	3.25	94.60	0.1028	16.81	69.81	0.1197	15.56	69.98	0.1219
60	2.77	91.83	0.1044	10.42	59.39	0.1298	12.10	56.88	0.1326
90	3.72	88.11	0.1065	8.47	50.92	0.1401	8.67	48.21	0.1440
150	8.89	79.22	0.1123	13.79	37.13	0.1641	17.82	30.39	0.1814
126 MICRONS				27.5 MICRONS			-8 MICRONS		
20	7.19	92.81	0.1038	13.46	86.54	0.1075	11.07	88.93	0.1049
40	11.05	81.76	0.1106	15.14	71.40	0.1183	13.29	75.64	0.1150
60	8.24	73.52	0.1166	10.09	61.31	0.1277	9.70	65.94	0.1232
90	9.07	64.45	0.1246	9.07	52.24	0.1384	10.40	55.54	0.1342
150	15.38	49.07	0.1428	13.71	38.53	0.1611	14.30	41.24	0.1557

TABLE 51

CALCULATED DATA FOR TEST 4-4

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
OVERALL				89 MICRONS			19.5 MICRONS		
20	13.06	86.94	0.1073	13.77	86.23	0.1077	14.96	85.04	0.1084
40	12.14	74.80	0.1156	13.34	72.89	0.1171	13.87	71.17	0.1185
60	8.23	66.57	0.1226	9.11	63.78	0.1252	9.57	61.60	0.1274
90	8.18	58.39	0.1309	9.38	54.40	0.1356	9.59	52.01	0.1387
150	12.29	46.10	0.1472	13.41	40.99	0.1562	13.88	38.13	0.1619
252 MICRONS				60 MICRONS			13.8 MICRONS		
20	0.53	99.47	0.1003	14.86	85.14	0.1084	14.47	85.53	0.1081
40	0.66	98.81	0.1006	14.75	70.39	0.1192	13.84	71.69	0.1181
60	0.72	98.09	0.1010	7.37	63.02	0.1260	9.90	61.79	0.1272
90	1.15	96.94	0.1016	8.34	54.68	0.1352	9.71	52.08	0.1386
150	3.07	93.87	0.1032	12.47	42.21	0.1539	14.47	37.61	0.1631
178 MICRONS				39 MICRONS			9.8 MICRONS		
20	2.16	97.84	0.1011	19.80	80.20	0.1117	18.57	81.43	0.1108
40	2.62	95.22	0.1025	15.27	64.93	0.1241	15.71	65.72	0.1234
60	2.62	92.60	0.1039	10.09	54.84	0.1350	10.33	55.39	0.1344
90	3.64	88.96	0.1060	8.22	46.62	0.1465	9.97	45.42	0.1484
150	8.76	80.20	0.1116	10.41	36.21	0.1662	11.80	33.62	0.1725
125 MICRONS				27.5 MICRONS			-8 MICRONS		
20	8.13	91.87	0.1043	15.64	84.36	0.1089	11.73	88.27	0.1064
40	9.56	82.31	0.1102	14.18	70.18	0.1194	12.60	75.67	0.1150
60	8.13	74.18	0.1161	9.67	60.51	0.1286	9.81	65.86	0.1232
90	9.19	64.99	0.1240	9.19	51.32	0.1396	8.81	57.05	0.1324
150	15.18	49.81	0.1417	13.11	38.21	0.1616	15.48	41.57	0.1551

TABLE 52

CALCULATED DATA FOR TEST 4-5

<u>TIME (SEC.)</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>	<u>% REC.</u>	<u>A-X</u>	<u>$1/(A-X)^{\frac{1}{2}}$</u>
<u>OVERALL</u>				<u>89 MICRONS</u>			<u>19.5 MICRONS</u>		
20	23.21	76.79	0.1141	12.22	87.78	0.1067	27.74	72.26	0.1176
40	14.82	61.97	0.1270	19.66	68.12	0.1212	17.60	54.66	0.1353
60	10.08	51.89	0.1388	15.56	52.56	0.1379	10.71	43.95	0.1509
90	9.00	42.89	0.1527	12.57	39.99	0.1581	9.46	34.49	0.1703
150	9.74	33.15	0.1737	10.06	29.93	0.1828	10.62	23.87	0.2047
<u>252 MICRONS</u>				<u>60 MICRONS</u>			<u>13.8 MICRONS</u>		
20	0.68	99.32	0.1003	35.14	64.86	0.1242	25.75	74.25	0.1160
40	0.81	98.51	0.1008	15.67	49.19	0.1426	18.26	55.99	0.1336
60	1.03	97.48	0.1013	8.78	40.41	0.1573	11.19	44.80	0.1494
90	1.89	95.59	0.1023	6.81	33.60	0.1725	9.93	34.87	0.1693
150	7.14	88.45	0.1063	6.02	27.58	0.1904	11.49	23.38	0.2068
<u>178 MICRONS</u>				<u>39 MICRONS</u>			<u>9.8 MICRONS</u>		
20	1.61	98.39	0.1008	38.51	61.49	0.1275	9.99	90.01	0.1054
40	3.89	94.50	0.1029	15.35	46.14	0.1472	23.24	66.77	0.1224
60	4.93	89.37	0.1057	9.35	36.79	0.1649	14.26	52.51	0.1380
90	7.23	72.34	0.1176	7.47	29.32	0.1847	9.76	42.75	0.1530
150	13.65	68.69	0.1207	7.29	22.03	0.2130	15.85	26.92	0.1928
<u>126 MICRONS</u>				<u>27.5 MICRONS</u>			<u>~8 MICRONS</u>		
20	5.58	94.42	0.1029	32.14	67.86	0.1214	28.82	71.18	0.1185
40	14.48	79.94	0.1118	17.07	50.79	0.1403	12.85	58.33	0.1309
60	14.58	65.36	0.1237	9.90	40.89	0.1564	12.37	45.96	0.1475
90	14.34	51.02	0.1400	8.69	32.20	0.1762	10.69	35.27	0.1684
150	13.29	37.73	0.1628	9.22	22.98	0.2096	11.98	23.29	0.2072

BIBLIOGRAPHY

ARBITER, NATHANIEL. FLOTATION RATES AND FLOTATION EFFICIENCY. AM. INST. MIN. MET. ENG. TRANS. T. P. 3193, P. 991 (1951)

BARLOW, PETER. BARLOW'S TABLE OF SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS AND RECIPROCAL OF ALL INTEGER NUMBERS UP TO 12,500. NEW YORK, CHEMICAL PUBLISHING CO., INC. 1941. 258 P.

DIETRICH, W. F., ENGEL, A. L., AND GUGGENHEIM, MORRIS. U. S. BUR. MINES REPT. INV. 3328. 1937. P. 26.

GAUDIN, A. M., GROH, J. O., AND HENDERSON, H. B. EFFECT OF PARTICLE SIZE ON FLOTATION. AM. INST. MIN. MET. ENG. T. P. 414 (1930)

GAUDIN, A. M., SCHUHMAN, R., JR., AND SCHLECHTEN, A. W. THE EFFECT OF SIZE ON THE BEHAVIOR OF GALENA PARTICLES. JOUR. OF PHYS. AND COLLOID CHEM. VOL. 46, PP. 902-910 (1942)

HINSHELWOOD, C. N. KINETICS OF CHEMICAL CHANGE. OXFORD, THE CLARENDON PRESS. 1940. 274 P.

HOUGEN, O. A., AND WATSON, K. M. CHEMICAL PROCESS PRINCIPLES, PART THREE, KINETICS AND CATALYSIS. NEW YORK, JOHN WILEY AND SONS, 1947. P. 828, PP. 938-942.

KIDD, R. L., AND WALL, W. L. EFFECT OF PARTICLE SIZE ON FLOTATION OF SPHALERITE. MINING AND METALLURGY. VOL. 14, PP. 421-422 (1933)

LAIDLER, K. J. CHEMICAL KINETICS. NEW YORK, MCGRAW HILL BOOK COMPANY, 1950. PP. 1-18.

MORRIS, T. M. MEASUREMENT OF FLOTATION RATE AS A FUNCTION OF PARTICLE SIZE. THESIS, MISSOURI SCHOOL OF MINES AND METALLURGY, ROLLA, MO. (1950)

MORRIS, T. M. MEASUREMENT OF EQUILIBRIUM FORCES BETWEEN AN AIR BUBBLE AND AN ATTACHED SOLID IN WATER. AM. INST. MIN. MET. ENG. TRANS. VOL. 187, PP. 91-96 (1950)

PRUTTON, C. F., AND MARON, S. H. FUNDAMENTAL PRINCIPLES OF PHYSICAL CHEMISTRY. NEW YORK, THE MACMILLAN COMPANY 1948. PP. 608-650.

SUTHERLAND, K. L. KINETICS OF THE FLOTATION PROCESS. JOUR. OF PHYS. AND COLLOID CHEM. VOL. 52, PP. 394-425 (1948)

TAGGART, A. F. HANDBOOK OF MINERAL DRESSING. NEW YORK, JOHN WILEY AND SONS. 1945. CHAP. 2, PP. 66-67, CHAP. 19, PP. 115-116.

VOLKOVA, Z. ACTA PHYSICOCHEMICA U.R.S.S. VOL. 22, 1947, P. 331.

WARK, I. W., AND COX, A. B. PRINCIPLES OF FLOTATION, I - AN EXPERIMENTAL STUDY OF THE EFFECT OF XANTHATES ON CONTACT ANGLES AT MINERAL SURFACES. AM. INST. MIN. MET. ENG. TRANS. VOL. 112, PP. 193-194 (1935)

ZUNIGA, H. GARCIA. BOL. MINERO SOC. NACL. MINERIA. CHILE. VOL. 47, 1935. PP. 83-86.

VITA

THE AUTHOR, WILLIAM EDWARD HORST, WAS BORN IN BLOOMINGTON, ILLINOIS, ON JANUARY 25, 1929. HE ATTENDED GRAMMAR SCHOOL IN GLENDALE, MISSOURI, AND HIGH SCHOOL IN KIRKWOOD, MISSOURI. AFTER BEING GRADUATED FROM KIRKWOOD HIGH SCHOOL IN 1947, HE ATTENDED THE SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI, AND RECEIVED THE DEGREE OF BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING ON JANUARY 24, 1951.

ON AUGUST 26, 1951 HE WAS UNITED IN MARRIAGE WITH MISS MARGARET ANN MILLARD OF WEBSTER GROVES, MISSOURI.

UPON ACCEPTANCE OF THIS THESIS BY THE FACULTY OF THE SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI, HE WILL BE ELIGIBLE FOR THE DEGREE OF MASTER OF SCIENCE IN METALLURGICAL ENGINEERING.